BROADWATER

RESOURCE REPORT No. 2

WATER USE AND QUALITY

FOR A

PROJECT TO CONSTRUCT AND OPERATE A

LIQUEFIED NATURAL GAS RECEIVING TERMINAL

IN

LONG ISLAND SOUND

LONG ISLAND, NEW YORK

UNITED STATES OF AMERICA

JANUARY 2006

PUBLIC

RESOURCE REPORT 2 – WATER USE AND QUALITY				
Minimum Filing Requirement	Location in Environmental Report			
• •Identify all perennial surface water bodies crossed by the proposed project and their water quality classification. (§ 380.12 (d) (1)).• •	Section 2.3			
 •Identify all waterbody crossings that may have contaminated waters or sediments. (§ 380.12 (d) (1)). • 	Section 2.3.6			
 • Identify watershed areas, designated surface water protection areas, and sensitive water bodies crossed by the proposed project. (§ 380.12 (d)(1)). 	Section 2.3.4			
• •Provide a table (based on National Wetlands Inventory [NWI] maps if delineations have not been done) identifying all wetlands, by milepost and length, crossed by the project (including abandoned pipeline), and the total acreage and acreage of each wetland type that would be affected by construction. (§ 380.12 (d) (1 & 4)).•	No wetlands are traversed by the Project			
 Discuss construction and restoration methods proposed for crossing wetlands, and compare them to staff's Wetland and Waterbody Construction and Mitigation Procedures. (§ 380.12 (d) (2)). 	No wetlands are traversed by the Project			
 Describe the proposed water body construction, impact mitigation, and restoration methods to be used to cross surface waters and compare to the staff's Wetland and Water Body Construction and Mitigation Procedures. (§ 380.12 (d) (2)). 	Section 2.5; see also Resource Report No. 1, Section 1 thru 1.5.			
• •Provide original NWI maps, or the appropriate state wetland maps if NWI maps are not available, that show all proposed facilities and include milepost locations for proposed pipeline routes. (§ 380.12 (d) (4)). • •	No wetlands are traversed by the Project			
• •Identify all U.S. Environmental Protection Agency (EPA)- or state-designated aquifers crossed. (§ 380.12 (d) (9)).	No EPA- or state-designated aquifers are traversed by the Project.			

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Environmental Information Request August 8, 2005

Requests for Additional Information from , Staff comments

Request	Location in Environmental Report
1. Describe marine currents and wave conditions in the project area associated with 100-year and 1,000-year storm events.	Section 2.3
2. Identify the Total Maximum Daily Load (TMDL) management zones for areas surrounding the FSRU and along the proposed pipeline route.	Section 2.3.3
3. Identify restrictions or guidelines for construction and operation of the proposed project in a waterbody designated as 303(d) impaired waters.	Section 2.3.3

Environmental Impacts to be Addressed in the Environmental Resource Reports

Request	Location in Environmental Report
1. Potential impacts of scouring of surface sediments along the pipeline and moo structure.	
2. Potential impacts of pipeline installating FSRU operations on the extent and many hypoxia in Long Island Sound.	
3. Potential impacts associated with consediments suspended in the water colupipeline installation.	
4. The size, location, and rationale for a zone, and the treatment methods and a pollutant concentrations of any waste associated with FSRU operations.	esulting
5. Detailed description of the magnitude and spatial extent of turbidity and sed associated with project construction, a methods proposed to avoid and minim potential impacts and satisfy specified thresholds. The discussion should incagency-approved modeling approach, assumptions, input parameters, and retabular, and graphical formats.	mentation and aize regulatory lude the

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	Request	Location in Environmental Report
1. a.	Describe marine currents in the Project area associated with a 100-year storm and a 1,000-year storm (and maximum currents and waves associated with the "maximum credible storm scenario").	Section 2.3
1. b.	Provide the size of any applicable regulatory mixing zone associated with water discharges.	Section 2.5.2.4
2. a.	Identify the threshold values that Broadwater used to suggest that turbidity and sedimentation would not be significant.	Section 2.5.1.1
2. b.	Describe the extent, magnitude, and duration of potential impacts to the water column associated with thermal impacts along the riser (associated with the yoke mooring structure [YMS]) and within the subseatrench prior to natural backfilling.	Section 2.5.1.1
2. c.	Specify the season and chemical additives (biocides, chlorine, etc) associated with discharge of hydrostatic test water.	Section 2.5.1.1
2.d.	If blasting may be used, describe the associated impacts to water resources.	See Resource Report No. 6, Section 6.4
3.	Describe potential impacts to water resources due to any toxic substance spills. Provide a comparison of the historic information on the range of bottom and surface currents in the Project area throughout the year with the currents measured by Broadwater in May 2005.	Sections 2.3 and 2.5.2.4
4.	Discuss the potential for the Long Island Sound to ice over during unusually cold winters (including identification of previous icing of the Sound) and the associated potential impact on the FSRU and mooring tower.	Section 2.3

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	Request	Location in Environmental Report
5.	Identify the agencies that reviewed and, if appropriate, approved the Broadwater water quality and sediment sampling procedures.	Section 2.3
6.	In Section 2.3.3 and Table 2-4, compare the water quality sampling results with the appropriate New York State or federal screening criteria.	Table 2-4
7.	In Section 2.3.5, revise the text related to potentially contaminated sediments to identify appropriate sediment screening criteria for contaminants in Table 2-6 that do not have applicable Technical and Operational Series (TOGS) standards.	Table 2-6
8.	Provide any agency comments on, and concurrence with, use of the MIKE3 model, input parameters, and assumptions for the Broadwater Project. Provide a tabular summary of the data output for the water quality/sedimentation modeling over time and space including the maximum turbidity under each scenario as an absolute value instead of simply identifying the values as being greater than 14 milligrams per liter. Also, provide a sensitivity analysis for the input variables.	Section 2.5.1.1, Figures 2-11g-a and 2-11h-a, and Appendix B
9.	Provide the technical basis for stating that Broadwater conservatively estimates that 20 percent of the solids removed from the trench would be suspended in the water column. Provide the results of the Broadwater grainsize analysis conducted as part of the May 2005 sediment survey.	Section 2.5.1.1 and Appendix F
10.	Confirm whether or not the average porosity of the sediment in the trench is 70 percent as reported in Section 2.1.1 of Appendix A, and, as appropriate, correct the input parameters for porosity, volume of solids per meter, volume suspended per meter, density of solids, and mass ejection rates as well as the	Section 2.1.1 of Appendix E and Appendix F

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	Request	Location in Environmental Report
	corresponding model output on the extent and magnitude of turbidity.	
11.	Provide the width of the spoil area along the pipeline that would be expected to have at least 4 inches of excavated sediment as well as the sedimentation depth at the edge of the 25-footwide spoil area and at the edge of the 300-footwide construction corridor. Provide the full citations for Kranz 1974 and Nichols et al. 1978 (cited in Section 2.5.1).	Sections 2.5.1.1 and 2.6
12.	Provide the technical justification for concluding that specialized trenching methods near the FSRU and the Iroquois tie-in would only result in minimal turbidity when neither the trenching methods nor the backfilling methods were identified or described in RR 2.	Section 2.5.1.1
13.	Discuss water quality monitoring plans that would be implemented during construction.	Section 2.5.2.4
14.	Clarify the location of the FSRU water discharge point(s) relative to the waterline.	Section 2.5.2.4
15.	Provide drafts of both the Ballast Water Management Plan and the Spill Prevention, Containment, and Countermeasures Plan.	Section 2.5.2.4 and Appendix D
16.	Summarize the anticipated water intake and discharge volumes for the current steampowered LNG carrier fleet relative to the next-generation of diesel/oil-powered LNG carriers, and specify the portion of the volumes used for standard ship operations/hoteling, and specifically for LNG unloading.	Section 2.5.2.3.3
17.	Specify the daily water intake for the sea chest during the peak throughput of 1.25 billion cubic feet per day.	Section 2.5.2.2
18.	Specify how Broadwater anticipates monitoring discharge concentrations of sodium hypochlorite and gray/black water in compliance with regulatory criteria. Provide correspondence with the NYSDEC regarding	Section 2.5.2.4 and Appendix A

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	Request	Location in Environmental Report
	permitting under the State Pollution Discharge Elimination System.	
19.	Describe the use of the emergency bilge discharge including potential volume, constituents, treatment, and monitoring.	Section 2.5.2.4
20.	Specify the source for central cooling water, and the anticipated frequency, duration, and magnitude of non-routine water use. In addition, specify how the discharge of central cooling water would have no impact on water temperature as indicated in Section 2.5.2.4.	Section 2.5.2.4
21.	Specify the total volume of water used by the side-shell water curtains of both the FSRU and an LNG carrier during the unloading of an LNG carrier (125,000m3 and 250,000m3 carriers).	Section 2.5.2.4

Environmental Information Request January 18, 2006

	Request	Location in Environmental Report
a.	Identify the threshold values that Broadwater used to conclude that turbidity (measured as total suspended solids) would not be significant.	Section 2.5.1.1
b.	Define the season in which hydrostatic testing would occur, specifically including both water intake and discharge.	Section 2.5.1.1
c.	Describe potential impacts to water quality and marine resources (e.g., sea turtles, marine mammals, and fish) from spills of LNG and chemicals used during construction and operation of the proposed Project.	Section 2.5.2.4
d.	Provide the screening criteria for all of the water quality sample and sediment sample analytes provided in Tables 2-4 and Tables 2-6.	Tables 2-4 and 2-6

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Environmental Information Request January 18, 2006

	Request	Location in Environmental Report
e.	Provide a tabular summary of the data output for the water quality/sedimentation modeling over time and space including the maximum	See Appendix C, new Figures 2-11g-a and 2-11h-a, and Appendices A and F.
	turbidity under each scenario as an absolute value. Provide tabular data for all resulting values from all three depths (surface, middle, and bottom). In addition, provide literature references for the settling rate and porosity used in the model.	To be submitted as a supplemental filing.
f.	Clarify the location of the treated wastewater discharge point(s) relative to the waterline.	Section 2.5.2.4 FSRU Discharges
g.	Specify the volume of water used by the side-shell water curtains for the FSRU and for the LNG carrier during the unloading of an LNG carrier (125,000 m3 and 250,000 m3 carriers).	Section 2.5.2.4 FSRU Discharges

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List of Acronyms and Abbreviations

ADCP acoustic Doppler current profilers

ASP Analytical Services Protocol

bcf billion cubic feet

bcfd billion cubic feet per day

BOD biological oxygen demand

BOD₅ biological oxygen demand (5-day)

CFR Code of Federal Regulations

CTDEP Connecticut Department of Environmental Protection

CWA Clean Water Act

°C degrees Celsius

°F degrees Fahrenheit

DO dissolved oxygen

EFH Essential fish habitat

EPA (United States) Environmental Protection Agency

FERC Federal Energy Regulatory Commission

FSRU Floating Storage and Regasification Unit

ft/s feet per second

IG inert gas

IGTS Iroquois Gas Transmission System

km kilometer

LA Load Allocation

LNG liquefied natural gas

m meter

MBR membrane bioreactor

MPN most probable number

m/s meters/second

m² square meter

xii PUBLIC

m³ cubic meter

m³/hr cubic meter per hour

mgd million gallons per day

mg/L milligrams per liter

NOAA National Oceanographic and Atmospheric Administration

NYSDEC New York State Department of Environmental Conservation

NYSDOS New York State Department of State

PAHs polycyclic aromatic hydrocarbons

PCBs polychlorinated biphenyls

ppm parts per million

ppt parts per thousand

SPDES State Pollution Discharge Elimination System

STV shell and tube vaporization

TMDL Total Maximum Daily Load

TSS total suspended solids

USACE United States Army Corps of Engineers

USGS United States Geological Survey

WLA Waste Load Allocation

YMS yoke mooring system

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2. WATER USE AND QUALITY

2.1 INTRODUCTION

Broadwater Energy, a joint venture between TCPL USA LNG, Inc., and Shell Broadwater Holdings LLC, is filing an application with the Federal Energy Regulatory Commission (FERC) seeking all of the necessary authorizations pursuant to the Natural Gas Act to construct and operate a marine liquefied natural gas (LNG) terminal and connecting pipeline for the import, storage, regasification, and transportation of natural gas. The Broadwater LNG Project (the Project) will increase the availability of natural gas to the New York and Connecticut markets through an interconnection with the Iroquois Gas Transmission System (IGTS). The FERC application for the Project requires the submittal of 13 Resource Reports, with each report evaluating Project effects on a particular aspect of the environment.

Resource Report 2 describes the surface water resources that may be affected by construction and operation of the proposed Project. Because the proposed Project will be located entirely within Long Island Sound (the Sound), this report focuses on resources within the Sound. This report also addresses the methods proposed for installing the Floating Storage and Regasification Unit (FSRU) and interconnecting the marine pipeline within the Sound, and specific mitigation measures proposed to minimize impacts.

The proposed Broadwater LNG terminal will be located in Long Island Sound, approximately 9 miles (14.5 kilometers [km]) from the shore of Long Island in New York State waters, as shown on Figure 2-1. The LNG terminal facilitates the sea-to-land transfer of natural gas. It will be designed to receive, store, and regasify LNG at an average throughput of 1.0 billion cubic feet per day (bcfd) and will be capable of delivering a peak throughput of 1.25 bcfd. The Project will deliver the regasified LNG to the existing interstate natural gas pipeline system via an interconnection to the IGTS pipeline. Onshore facilities are discussed in the Onshore Facility Resource Reports.

The proposed LNG terminal will consist of an FSRU that is approximately 1,215 feet (370 meters [m]) in length, 200 feet (60 m) in width, and rising approximately 80 feet (25 m) above the water line to the trunk deck. The FSRU's draft is approximately 40 feet (12 m). The freeboard and mean draft of the FSRU will generally not vary throughout operating conditions. This is achieved by ballast control to maintain the FSRU's trim, stability, and draft. The FSRU will be designed with a net storage capacity of approximately 350,000 cubic meters [m³] of LNG (equivalent to 8 billion cubic feet [bcf] of natural gas), with base vaporization capabilities of 1.0 bcfd using a closed-loop shell and tube vaporization (STV) system. The LNG will be delivered to the FSRU in LNG carriers with cargo capacities ranging from approximately 125,000 m³ up to a potential future size of 250,000 m³ at a frequency of two to three carriers per week.

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Source: ESRI StreetMap, 2002.

Figure 2-1
Proposed Broadwater Project
Location in Long Island Sound

The FSRU will be connected to the send-out pipeline, which rises from the seabed and is supported by a stationary tower structure. In addition to supporting the pipeline, the stationary tower also serves the purpose of securing the FSRU in such a manner to allow it to orient in response to prevailing wind, wave, and current conditions (i.e., weathervane) around the tower. The tower, which is secured to the seabed by four legs, will house the yoke mooring system (YMS), allowing the FSRU to weathervane around the tower. The total area under the tower structure, which is of open design, will be approximately 13,180 square feet (1,225 square meters [m²]).

A 30-inch-diameter natural gas pipeline will deliver the vaporized natural gas to the existing IGTS pipeline. It will be installed beneath the seafloor from the stationary tower structure to an interconnection location at the existing 24-inch-diameter subsea section of the IGTS pipeline, approximately 22 miles (35 km) west of the proposed FSRU site. To stabilize and protect the operating components, sections of the pipeline will be covered with engineered back-fill material or spoil removed during the lowering operation. Figure 2-1 presents the proposed pipeline route.

The offshore Project components will not impact groundwater or wetland resources. Therefore, no discussion of these resources is included in this Resource Report. Onshore facilities are described in the Onshore Facility Resource Reports.

2.2 GROUNDWATER RESOURCES

The proposed Project is located entirely within Long Island Sound. Therefore, no groundwater resources will be affected by installation or operation of the FSRU and subsea pipeline.

2.3 SURFACE WATER

The proposed Project is located entirely within Long Island Sound. Long Island Sound is approximately 112 miles (180 km) long and 21 miles (34 km) across at its widest point. The total area of the Sound is 1,300 square miles (3,370 square km), containing approximately 2.4 trillion cubic feet (68 billion m³) of water. Long Island Sound is divided into three major basins: eastern, central, and western. The proposed FSRU will be located in the central basin, while the interconnecting subsea pipeline will be located in the central and western basins. The eastern basin is the deepest and narrowest of the three basins. The central basin is the widest, with depths ranging from 60 to 130 feet (18 to 40 m). The western basin is characterized by shallower depths and a predominantly mud substrate. Stratford Shoal, a shallow area located in the western portion of the Project area, serves as the boundary between the central and western basins.

To verify surface water and sediment conditions present within the Project area, Broadwater conducted extensive field surveys in April and May 2005. Prior to undertaking the field surveys, a Sampling and Analysis Plan was provided to the regulatory agencies for review and comment. Of the agencies consulted, only the New York State Department of Environmental Conservation (NYSDEC) provided written approval of the final Plan (see Appendix A). The Sampling and Analysis Plan and field

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data results have been submitted to FERC under separate cover as part of the *Spring 2005 Environmental Sampling Report for a Project to Construct and Operate an LNG Receiving Terminal in Long Island Sound* (E & E 2005). The results of this field effort as they apply to specific water and sediment resources are summarized in the sections presented below.

Metocean Conditions

Long Island Sound has semi-diurnal tides, which range from about 2.6 feet (0.8 m) at the eastern end to more than 7.2 feet (2.2 m) at the western end. Strong tidal currents in excess of 4 knots (6.7 feet/second [ft/s]) occur at the Race. The Race is the eastern entrance to Long Island Sound, between Fisher's Island and Gull Island, including Valiant Rock. Measured bottom currents in the central basin of the Sound have speeds between 0.7 and 1.0 ft/s (0.2 and 0.3 meter per second [m/s]), and bottom currents in the western basin of the Sound generally have speeds less than 0.7 ft/s (0.2 m/s). Local enhancements of bottom tidal currents in excess of 1 ft/s (0.3 m/s) exist near headlands and over shoal areas (e.g., Stratford Shoal).

To verify existing tidal currents within the Project area, three acoustic Doppler current profilers (ADCPs) were deployed during the course of field surveys. One ADCP was deployed near the proposed tie-in with the IGTS system, one was deployed near the proposed FSRU location, and a third was deployed at the proposed crossing of Stratford Shoal. The ADCPs were deployed for one entire tidal cycle in May 2005.

Tidal currents at the IGTS tie-in location, which is located in the western basin of the Sound, averaged 0.6 ft/s (0.2 m/s). Tidal currents at the location of the proposed FSRU averaged 0.8 ft/s (0.3 m/s). The existing physiographic conditions present at Stratford Shoal resulted in an average current of 1.3 ft/s (0.4 m/s). These values demonstrate that data obtained from the ADCPs was within the same range as the historic current values described above. The complete data set collected from the ADCPs is presented in Section 6 of the *Spring 2005 Environmental Sampling Report for a Project to Construct and Operate an LNG Receiving Terminal in Long Island Sound* (E & E 2005).

The weather conditions within Long Island Sound are relatively benign, but strong winds associated with hurricanes or other storms are a feature at this location. These winds may generate significant waves, depending on the direction and duration of the wind. Approximately 25 tropical storms have affected Long Island Sound since 1938, 15 of which have generated significant wave heights above 6.6 feet (2 m). Based on historical data, a 100-year storm event would be expected to have a significant wave height of 14.2 feet (4.3 m) and a 1,000-year storm event would be expected to have a significant wave height of 18.8 feet (5.7 m) (Cox and Swail 1999; Swail and Cox 2000; Swail et al. 2001; Cardone et al. 2000). Current data is not available from these historical storm events. Therefore, the Project design utilized maximum recorded storm data from the hurricanes of 1938 and 1944, as discussed below.

As the FSRU is a floating structure, it is imperative that the mooring arrangement be such that the terminal is able to remain on station. For this reason, Broadwater has increased the survivability criteria for the yoke mooring system from the more typical design

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criteria of a 100-year storm event to credible storm scenarios well in excess of those experienced in the recent history of the region. By way of comparison, the hurricane experienced in the region on September 21, 1938, was equivalent to a 50-year storm event, and the September 14, 1944, hurricane was the equivalent of an approximately 75-year storm, based on Broadwater's analysis of historical weather data. Consequently, the yoke mooring system would be capable of surviving events of greater magnitude than both of these events, which had wave heights of approximately 12 feet (3.8 m) and 13.3 feet (4 m), respectively.

In addition to strong winds generated by storm events, winter weather conditions in Long Island Sound were also evaluated in the context of ice formation. Meteorological data does not indicate that Long Island Sound ices over in the winter (http://www.natice.noaa.gov/). Anecdotal information indicates that the Sound may have iced over in past years, but this is not supported by local weather data. The potential formation of ice in Long Island Sound has not been shown to be an impediment to vessel traffic, and other vessels and local ferries continue to operate throughout the winter months. Several vessels transit the Sound on a daily basis in both the winter and summer months. Winter vessel traffic declines for the recreational boater, but the Sound is still used by larger vessels such as freighters and tankers delivering to the various ports on Long Island Sound. Available marine data that has been collected and evaluated for the Project considered the scenario of the Sound icing over, but it was dismissed as having no potential to impact the Project, since surface ice would not exert any forces on the structures that were not considered during the design process.

Temperature

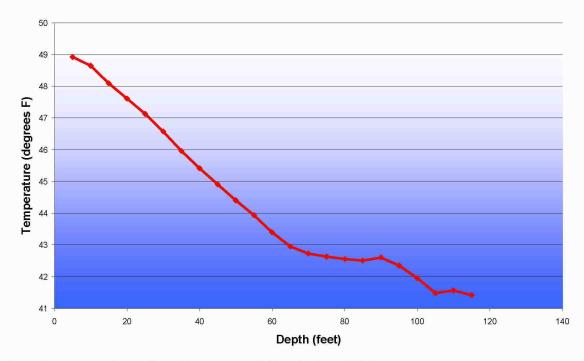
Overall, water temperatures in Long Island Sound average 38.5 degrees Fahrenheit [°F] (3.6 degrees Celsius [°C]) in January, with temperatures in the western Sound approximately 1.8 •F (1 °C) cooler on average than those in the eastern Sound. The average temperature in Long Island Sound does not exceed 50 °F (10 °C) until May. During July, August, and September, Long Island Sound exhibits the highest water temperatures for the year. It is also only during this time frame that a significant temperature gradient exists from the top to the bottom of the water column. Temperatures at, or near, the surface range from 65 °F to 77 °F (18 °C to 25 °C) (), with temperatures at depths of 65 feet to 98 feet (20 m to 30 m measuring as much as 9 •F (5° C) cooler.

In order to assess existing site-specific conditions for the proposed pipeline route, 597 water temperature readings were collected using a Seabird-CTD water quality meter. These readings were collected at 5-foot (1.5-m) intervals continuously throughout the water column at 27 sample locations along the pipeline route. Although the temperature data reflect only a snapshot of the temperature regime in the Sound, it depicts the temperature gradation from top to bottom. No identifiable trends were apparent from east to west across the length of the Project area. The data collected is supportive of the historical data trends for the Sound. Temperature data were compiled and averaged for each 5-foot (1.5-m) depth interval and are plotted on Figure 2-2. The temperature pattern shows a decrease of approximately 1 °F (0.6 •C) for every 20 feet (6.1 m) of depth.

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Figure 2-2 Average Temperatures Measured during the Spring 2005 Field Survey

Temperature Average (degrees F)



Note: Temperature data collected between April 15 and May 5, 2005.

Weather patterns significantly affect temperatures within Long Island Sound. Hot dry summers with mild breezes allow the Sound to thermally stratify, sealing off the bottom layer of water below a thermocline. By fall, climate conditions change, allowing more complete mixing within Long Island Sound. During the fall, temperatures within Long Island Sound are fairly consistent from top to bottom, averaging 18 °C (65 °F) in October, 13 °C (55 °F) in November, and 8 °C (45 °F) in December.

Salinity

Long Island Sound receives hydrologic inputs from both saline and freshwater sources. Due to its size and the differing hydrologic inputs, salinity varies throughout the Sound. The Sound has two connections with the ocean. The eastern portion of Long Island Sound maintains fairly constant salinity levels via input from the Atlantic Ocean through Block Island Sound, with average salinities on the order of 27 parts per thousand (ppt) to 30 ppt. In the western portion of Long Island Sound, lower-salinity water enters from New York Harbor through the East and Harlem Rivers. Within the western portion of Long Island Sound, salinity variations are more evident due to the seasonal influx of freshwater from adjacent uplands. Due to the significant inflows of freshwater, the salinity levels in the western portion of the Sound may be 1 ppt to 2 ppt below levels in the eastern portion of the Sound. The majority of the freshwater content of the Sound, approximately 90%, comes from the Connecticut, Housatonic, and Thames Rivers (EPA)

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2005), which are located north of the Project area along the southern shore of Connecticut.

Site-specific salinity conditions along the proposed pipeline route were evaluated by collecting 597 readings using a Seabird-CTD water quality meter. These readings were collected at 5-foot (1.5-m) intervals continuously throughout the water column at 27 sample locations along the pipeline route. The results of the readings from the water quality meter indicated that salinity values are consistent throughout the water column and vary only slightly along the east—to-west pipeline route, with a minimum value of 24.7 ppt and a maximum value of 26.6 ppt. The average salinity for all 597 sample readings was 25.7 ppt. This value is much lower than seawater in the open ocean, which has an average value of 35 ppt, but it is consistent with reported salinities for the Sound. The decreased salinities in the Sound are due to the physical structure of the Sound as a large inlet with significant freshwater inputs from riverine systems, including the Connecticut, Housatonic, and Thames Rivers (EPA 2005).

2.3.1 Watershed Description

The Long Island Sound watershed consists of a 16,000-square-mile (41,400-square-km) drainage basin that includes much of New England and Long Island. Over 8 million people live within this watershed, with the coastal areas being among the most populated (EPA 2005). The major rivers entering Long Island Sound flow through Connecticut, including the Housatonic, Quinnipiac, Connecticut, Norwalk, Pawcatuck, and Thames. As mentioned previously, approximately 90% of the freshwater content of the Sound comes from the Connecticut, Housatonic, and Thames rivers.

2.3.2 Surface Water Standards and Classifications

Within the Project area, Long Island Sound is designated by the New York State Department of Environmental Conservation (NYSDEC) as a Class SA water. The best use of Class SA waters is shellfishing for market purposes and primary and secondary contact recreation and fishing. These waters are also suitable for fish propagation and survival. The physical water quality criteria that apply to this water class designation, as presented in NYSDEC Sec. 1312 (Water Quality Related Effluent Limitations) are outlined in Table 2-1.

Table 2-1 Physical Water Quality Criteria

Parameter	Water Classes	Standard
Taste, color, and toxic and other deleterious substances	SA	None in amounts that will adversely affect the taste, color, or odor thereof, or impair the waters for their best usages.
Turbidity	SA	No increase that will cause a substantial visible contrast to natural conditions.
Suspended colloidal and settleable solids	SA	None from sewage, industrial wastes, or other wastes that will cause deposition or impair the waters for their best usages.

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Table 2-1 Physical Water Quality Criteria

Parameter	Water Classes	Standard
Oil and floating substances	SA	No residue attributable to sewage, industrial wastes, or other wastes or visible oil film, nor globules of grease.
Garbage, cinders, ashes, oils, sludge and other refuse	SA	None in any amount.
Phosphorus and nitrogen	SA	None in amounts that will result in growths of algae, weeds, or slimes that will impair the water for their best usages.
рΗ	SA	The normal range shall not be extended by more than one-tenth (0.1) of a standard pH unit.
Dissolved oxygen	SA	Shall not be less than 5.0 milligrams per liter (mg/L) at any time.
Dissolved solids	SA	Shall not exceed 200 mg/L. Shall be kept as low as practicable to maintain the best usage of waters but in no case shall exceed 500 mg/L.
Total Coliform (number per 100 ml)	SA	The median most probable number value in any series of representative samples shall not be in excess of 70.

In addition, NYSDEC has promulgated guidance for thermal discharges and mixing zones. This guidance states that all thermal discharges to the waters of the state shall ensure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water. Criteria governing these discharges include the following:

- The natural seasonal cycle shall be retained;
- Annual spring and fall temperature changes shall be gradual;
- Large day-to-day temperature fluctuations due to heat of artificial origin shall be avoided;
- Development or growth of nuisance organisms shall not occur in contravention of water quality standards;
- Discharges that would lower receiving water temperatures shall not cause a violation of water quality standards;
- To protect aquatic biota from severe temperature changes, routine shutdown of an entire thermal discharge at any site shall not be scheduled during the period from December through March; and

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- For discharges to coastal waters:
 - The water temperature at the surface of coastal water shall not be raised more than 4° F (2.2•C) from October through June, or more than 1.5 °F (1•C) from July through September, over that which existed before the addition of heat of an artificial origin.
 - The water temperature at the surface of coastal water shall not be lowered more than 4 °F (2.2 •C) from October through June, or more than 1.5 °F (1 •C) from July through September, from that which existed immediately prior to such lowering.

Mixing zone criteria also applies to all waters of the state receiving thermal discharges. This includes numerical limits for mixing zones (i.e., linear distances from the point of discharge, surface area involvement, or volume of receiving water entrained in the thermal plume). Conditions in the mixing zone shall not be lethal, in contravention of water quality standards, to aquatic biota that enter the zone. The location of mixing zones for thermal discharges shall not interfere with spawning areas, nursery areas, or fish migration routes. In addition, the location, design, construction, and capacity of cooling water intake structures in connection with point-source thermal discharges shall reflect the best technology available for minimizing adverse environmental impacts.

2.3.3 Existing Water Quality

Water quality within Long Island Sound is affected by several point and non-point sources of pollution. Point sources of pollution include effluent from sewage treatment plants, industrial discharges, and port and marina operations. Non-point sources of pollution include storm water runoff, agricultural runoff, and atmospheric deposition. Input from these sources contributes to nitrogen pollution, sediment contamination, and habitat degradation and loss.

Hypoxia, or low levels of dissolved oxygen (DO), is considered to be the most serious water quality issue in Long Island Sound (LISS 1994). Hypoxia occurs primarily during the summer, when the waters of the Sound stratify, and high nutrient loading results in depressed DO levels at bottom depths within the Sound. Stratification prevents the mixing of oxygen-rich surface waters of the Sound with oxygen-depleted bottom waters. The western and central basins of the Sound exhibit lower biological abundance and diversity when hypoxic conditions occur. Hypoxia, which occurs largely in the deeper waters of the western basin, impairs habitat required by finfish and shellfish for their survival. Nitrogen inputs associated with discharges from sewage treatment plants have been identified as the main cause of hypoxia in the Sound, with the highest inputs arising from the densely populated New York City area.

DO levels in the Sound vary both seasonally and spatially. The levels tend to be constant during winter, averaging between 11 mg/L and 13 mg/L. DO levels tend to be slightly lower during summer, as warm water is less able to absorb oxygen. In general, average DO levels in the Sound range from 6.5 mg/L to 10 mg/L, depending on water temperature and location. DO levels above 4.8 mg/L are considered excellent and supportive of marine life. When hypoxic conditions develop, DO levels drop

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significantly below 4.8 mg/L, and in some cases drop to near anoxic. Figure 2-3 shows the extent of hypoxia within Long Island Sound during August 2003 and August 2004. During the hypoxia event in August 2003, 186 square miles (482 square km) of Long Island Sound experienced DO levels below 2 mg/L, and 345 square miles (893 square km) experienced levels below 3 mg/L. In addition, the 62 square miles (161 square km) affected by DO levels below 1 mg/L was the largest recorded during the 13 years the Connecticut Department of Environmental Protection (CTDEP) has been mapping summer hypoxia in Long Island Sound (CTDEP 2005).

In order to assess existing site-specific dissolved oxygen (DO) conditions in the area of the proposed pipeline route, 597 DO readings were collected using a Seabird-CTD water quality meter. These readings were collected at 5-foot intervals continuously throughout the water column at 27 sample locations along the pipeline route. The results of the readings included DO values ranging from 4.9 mg/L to 11.1 mg/L for samples at a depth of 5 feet (1.5 m); 8.9 mg/L to 11.3 mg/L from 20 to 40 feet (6 to 12 m); 8.9 mg/L to 11.2 mg/L from 45 to 65 feet (14 to 20 m); 8.9 mg/L to 10.3 mg/L from 70 to 90 feet (21 to 27 m); and 8.9 mg/L to 9.6 mg/L from 100 to 130 feet (30 to 40 m). The average measured DO value for the entire Project area was 9.5 mg/L. The field DO values support the historical data collected for the Sound.

In addition to examining DO as an independent value, DO concentrations were compared to water temperature data from the same sample location and depth to determine whether a trend exists. Based on this comparison, the data shows that DO was not significantly affected by decreases in water temperature. However, any impact that temperature may have on DO is likely not apparent in this data set since it was collected in the months of April and May and does not show any major stratification in the water column, which is related to the warmer temperatures and high nutrient loading that often occurs in the later summer months.

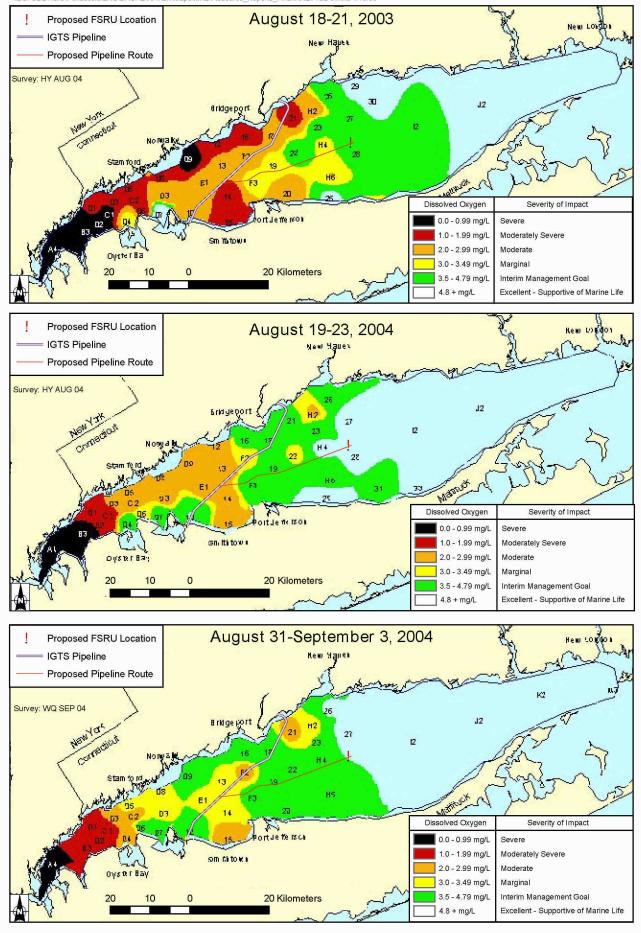
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Data for pH was collected in conjunction with other water quality parameters using the Seabird-CTD water quality meter along the proposed pipeline route. A total of 597 pH readings were recorded, and analysis of the data across all stations and depths resulted in an average pH value of 8.5, with a minimum of 7.4 and a maximum of 8.8. This variability of the site-specific pH values was insignificant, with a standard deviation of only 0.09 for the entire data set. These values indicate that the pH of the water column is consistent throughout the Project area.

TMDL Restrictions

Due to concerns regarding contaminant inputs to Long Island Sound, NYSDEC and CTDEP have developed a Total Maximum Daily Load (TMDL) for biological oxygen demand. Biological oxygen demand has been identified as a major problem for Long Island Sound with regard to hypoxia and development of hypoxic and anoxic conditions in portions of the water column. The TMDL was developed based on the impaired use designations assigned by New York State listed below:

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Source: Connecticut Department of Environmental Protection, Long Island Sound Water Quality Monitoring Program. http://dep.state.ct.us/wtr/lis/monitoring/monsum.htm.

Figure 2-3 Historical Dissolved Oxygen Levels

- Atlantic Ocean/Long Island Sound Drainage Basin Individual water body segment with impairment requiring TMDL development.
- Atlantic Ocean/Long Island Sound Drainage Basin Multiple segment categorical (shellfishing) water bodies requiring TMDL development.

Section 303(d)(1)(C) of the Clean Water Act (CWA) and the United States Environmental Protection Agency's (EPA's) implementing regulations (40 CFR Part 130) require states to identify water bodies that do not meet water quality standards after application of the technology-based effluent limitations required by the CWA. New York and Connecticut identified Long Island Sound as "water quality limited" due to hypoxia and a priority area for development of a TMDL. By definition, a TMDL specifies the allowable pollutant loading from all contributing sources (e.g., point sources, non-point sources, and natural background) that will attain the applicable water quality standards with seasonal variations and a margin of safety. The margin of safety takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. In essence, a TMDL defines the assimilative capacity of the water body to absorb a pollutant and still meet water quality standards. To address the problem of hypoxia, EPA has been proceeding with a phased approach to nitrogen reduction, allowing the program to move forward in stages as more information is obtained to support more aggressive steps.

On February 5, 1998, the states of Connecticut and New York and the EPA adopted a plan for Phase III Actions for Hypoxia Management, including nitrogen reduction targets of 58.5% for 11 "management zones" that comprise the Connecticut and New York portions of the Long Island Sound watershed. A preliminary draft of the TMDL was completed by July 1998. However, based on evolving national policy on TMDLs, EPA required the TMDL to identify how the total load allocation will be distributed between point sources (the Waste Load Allocation [WLA]) and non-point sources (the Load Allocation [LA]). Compliance with this requirement delayed the release of the draft TMDL by the states of Connecticut and New York until November 1999 (NYSDEC and CTDEP 2000). In April 2001, the Long Island Sound Office of the EPA issued a letter approving the TMDL proposed by New York and Connecticut. The planned implementation date for Phase III, which forms the substance of the TMDL, is 2014 (CTDEP 2001).

As part of the Phase III actions, Long Island Sound and the surrounding land areas have been divided into management zones with load designations relating to the TMDL and nitrogen input for point (WLA) and non-point sources (LA) (see Figure 2-4). Table 2-2 presents the TMDL designated for each management zone. The FSRU will be located in Zone 7, which has the lowest current loading levels of point and non-point source pollution in the central and western portions of Long Island, as well as the lowest target levels. The pipeline will traverse both Zone 7 and Zone 5, with Zone 5 encompassing the western portion of the route, including Stratford Shoal. Vessels used during pipeline construction will minimize discharges that impact BOD in these areas, which can adversely affect dissolved oxygen levels and cause hypoxia.

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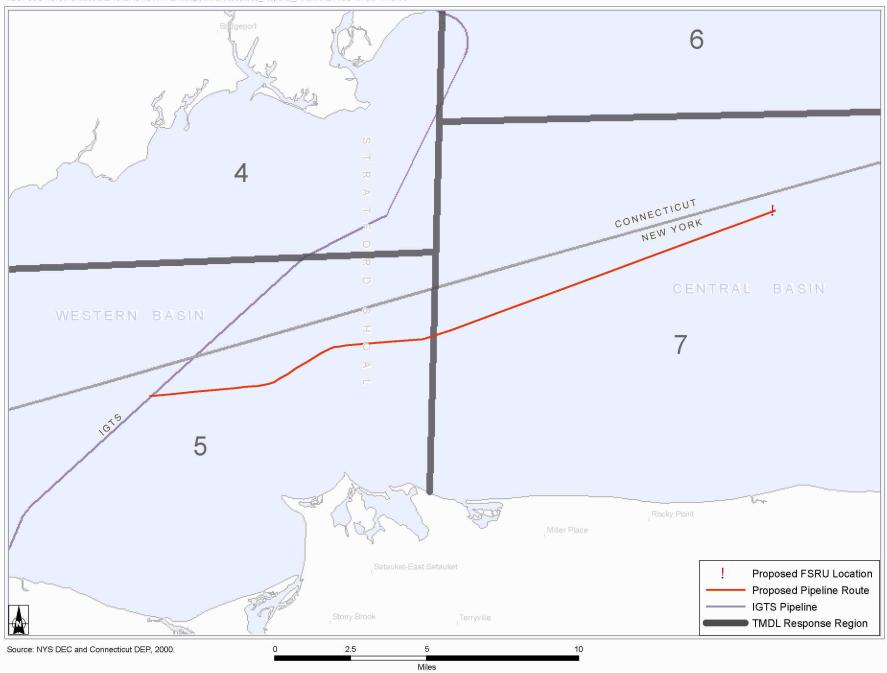


Figure 2-4 Long Island Sound Nitrogen Managment Zones

Table 2-2 In-basin Phase III Nitrogen TMDL/WLA/LA by Management Zone

Management Zone	Point Source Load (tons/yr)	Non-point Source Load (tons/yr)	Total Nitrogen Load (tons/yr)	WLA Target Load (tons/yr)	LA Target Load (tons/yr)	Load Reduction from Baseline (tons/yr)
1	1,243	1,852	3,095	454	1,787	854
2	2,805	2,473	5,278	1,024	2,350	1,904
3	2,103	999	3,102	768	937	1,397
4	1,669	1,652	3,321	609	1,575	1,137
5	948	475	1,423	346	443	634
6	1,108	545	1,653	404	506	743
7	837	190	1,027	325	172	530
8	18,081	0	18,081	7,504	0	10,577
9	9,417	0	9,417	3,908	0	5,509
10	484	275	759	175	252	332
11-west	191	393	584	37	357	190
11-east	14	34	48	2	31	15
Total	38,900	8,888	47,788	15,556	8,410	23,822

Source: 2001 EPA.

The FSRU, will have up to seven point-source discharges. As part of the design, BOD discharges from the FSRU have been minimized. All discharges from the FSRU will meet NYSDEC's State Pollutant Discharge Elimination System (SPDES) standards to minimize impacts. There are no specific restrictions or guidelines for construction and operation activities in impaired waters, only effluent limitations that will be implemented by limiting BOD discharges during pipeline construction and FSRU operation. If it is determined that gray and black water cannot meet SPDES standards, then gray and black water will be held and shipped to shore for treatment at an approved facility.

Field Sampling Results

As discussed above, the water quality of Long Island Sound is influenced by many physical factors, including physico-chemical inputs and geographic characteristics. To evaluate the physical quality of the water in the vicinity of the proposed pipeline route, water quality samples were collected from eight sampling locations. These sampling locations were co-located with sediment sampling locations and collected as part of the same field effort. Water quality samples were collected from eight locations (C-1, C-3, IC-6, MG-5, C-15, C-19, C-27, and C-28) along the proposed pipeline route. The field effort included collection of a water quality sample from three discrete depths at each location. The discrete depths were defined as just below the water surface (<5 feet [1.5 m]), at the midpoint in the water column, and the bottom of the water column (5 feet [1.5 m] from the bottom). Samples were collected in 1-liter volumes from each of the discrete

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depths with the exception of samples for biological oxygen demand, which were collected in a 250-ml amber glass bottle to protect the integrity of the sample until analysis. Samples were sent to the laboratory on the same day as sample collection due to short holding times between collection and analysis. A summary of the water quality analyses completed for the Project is presented in Table 2-3.

Table 2-3 Summary of Water Sample Analyses

Test Description	EPA Method Number	Number of Samples
Total Suspended Solids (TSS)	EPA 160.2	8
Colloidal/Settleable Solids	EPA 160.5	8
Chlorides	EPA 300	8
Total Organic Nitrogen	SM4500-NC	8
Total Phosphorus	EPA 365.3	8
Fecal Coliform Bacteria	SM4221C	8
Total Coliform Bacteria	SM4221B	8
Biological oxygen demand	SM5210B	8
Chemical oxygen demand	EPA 410.1	8
Ammonia (as N)	EPA 350.3	8

Once the laboratory analysis was completed, data package results were received and data was put through a rigorous quality assurance/quality control (QA/QC) program according to NYSDEC Analytical Services Protocol (ASP) requirements. Upon completion of the QA/QC review, positive results were evaluated, and a comparative evaluation to historical sound conditions and available water quality criteria was performed to assess the water quality. The water quality results are presented below in Table 2-4.

Results of the sample analysis confirm that the water quality parameters along the proposed pipeline route fall in the range of the natural conditions present in the eastern basin of Long Island Sound. This area is generally not impacted by increased inputs from sewage and other contaminants from the surrounding coastlines that would impact water quality.

2.3.4 Sensitive Surface Waters

Sensitive water bodies are those: (1) containing habitat for threatened and endangered species, (2) containing outstanding or exceptional water quality, (3) not meeting water quality standards associated with the water's designated beneficial uses, (4) supporting significant fisheries, (5) located in a sensitive or protected watershed, or (6) listed as a state or federal Wild and Scenic River. In New York, sensitive waters bodies include waters designated as:

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Table 2-4 Summary of Positive Analytical Results for Water Quality Samples, May 2005

Analyte	NYSDEC Screening Criteria ⁽¹⁾	EPA Screening Criteria ⁽²⁾	Samp le ID: Date:	C-1-DS-W 04/29/05	C-1-DM-W 04/29/05	C-1-DB-W 04/29/05	C-3-DS-W 04/22/05	C-3-DM-W 04/22/05
Anions (mg/L)								
Chloride	NA	NA		22400	24200	25500	21900	28300
Sulfate	NA	NA		2860	3350	3680	3080	3930
General Analytical (mg/L)								
Ammonia	NA	NA		0.020 U	0.025	0.035	0.020 U	0.020 U
Biochemical Oxygen Demand	NA	NA		2.0 U				
Chemical Oxygen Demand	NA	NA		838 J	1070 J	1020 J	739 J	843 J
Colloidal Solids	NA	NA		8.0	4.0 U	4.0	13.0 J	4.0 UJ
Non-Filterable Residue (103 C)	NA	NA		10 U	10 U	10 U	13.0 J	10 UJ
Total Organic Nitrogen	NA	0.32		0.63	0.72	0.61	0.16	0.21
Total Phosphorous	NA	0.1	-	0.010 U				
Total Residue (103 C)	NA	NA		27600	28700	28500	29600	32900

J = Estimated value.

U = Not detected at the reported value.

mg/L = Milligrams per liter

S - Surface, M - Middle, B - Bottom

NA = Screening criteria not available for this analyte in saline water.

(1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations, June 1998 (2) EPA Office of Water, National Recommended Water Quality Criteria, 2002.

(2) Highlighted values exceed the EPA screening criteria.

Source: Ecology and Environment, Inc 2005

Table 2-4 Summary of Positive Analytical Results for Water Quality Samples, May 2005

Analyte	NYSDEC Screening Criteria ⁽¹⁾	EPA Screening Criteria ⁽²⁾	Samp le ID: Date:	C-3-DB-W 04/22/05	IC-6-DS-W 04/27/05	IC-6-DM-W 04/27/05	IC-6-DB-W 04/27/05	MG-5D-DS-W 04/21/05
Anions (mg/L)								
Chloride	NA	NA		25800	21300	26900	27400	24900
Sulfate	NA	NA		3500	2640	3310	3380	3360
General Analytical (mg/L)								
Ammonia	NA	NA		0.020 U	0.020 U	0.020 U	0.027	0.020 U
Biochemical Oxygen Demand	NA	NA		2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
Chemical Oxygen Demand	NA	NA		739 J	634 J	1600 J	1830 J	659 J
Colloidal Solids	NA	NA		5.0 J	4.0 U	4.0 U	4.0 U	4.0 J
Non-Filterable Residue (103 C)	NA	NA		10 UJ	10 U	10 U	10 U	53.0 J
Total Organic Nitrogen	NA	0.32		0.10 U	0.69	0.71	0.63	0.10 U
Total Phosphorous	NA	0.1		0.010 U	0.010 U	0.010 U	0.010 U	0.010 U
Total Residue (103 C)	NA	NA		28900				40800

J = Estimated value.

U = Not detected at the reported value.

mg/L = Milligrams per liter

S - Surface, M - Middle, B - Bottom

NA = Screening criteria not available for this analyte in saline water.

(1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations, June 1998 (2) EPA Office of Water, National Recommended Water Quality Criteria, 2002.

(2) Highlighted values exceed the EPA screening criteria.

Source: Ecology and Environment, Inc 2005

Table 2-4 Summary of Positive Analytical Results for Water Quality Samples, May 2005

Analyte	NYSDEC Screening Criteria ⁽¹⁾	EPA Screening Criteria ⁽²⁾	Samp le ID: Date:	MG-5D-DM-W 04/21/05	MG-5-DB-W 04/21/05	C-15-DS-W 04/26/05	C-15-DM-W 04/26/05	C-15-DB-W 04/26/05
Anions (mg/L)								
Chloride	NA	NA		26500	24600	23000	28800	32400
Sulfate	NA	NA		3250	3800	3100	3960	4180
General Analytical (mg/L)								
Ammonia	NA	NA		0.020 U	0.020 U	0.020 U	0.020 U	0.052
Biochemical Oxygen Demand	NA	NA		2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
Chemical Oxygen Demand	NA	NA		782 J	843 J	1850 J	3430 J	1540 J
Colloidal Solids	NA	NA		33.0 J	12.0 J	21.0	6.0	5.0
Non-Filterable Residue (103 C)	NA	NA		17.0 J	12.0 J	21.0	10 U	10 U
Total Organic Nitrogen	NA	0.32		0.10 U	0.15	0.80	0.57	0.62
Total Phosphorous	NA	0.1		0.010 U	0.010 U	0.010 U	0.010 U	0.010 U
Total Residue (103 C)	NA	NA		30900	36800			

J = Estimated value.

U = Not detected at the reported value.

mg/L = Milligrams per liter

S - Surface, M - Middle, B - Bottom

NA = Screening criteria not available for this analyte in saline water.

(1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations, June 1998 (2) EPA Office of Water, National Recommended Water Quality Criteria, 2002.

(2) Highlighted values exceed the EPA screening criteria.

Source: Ecology and Environment, Inc 2005

Table 2-4 Summary of Positive Analytical Results for Water Quality Samples, May 2005

Analyte	NYSDEC Screening Criteria ⁽¹⁾	EPA Screening Criteria ⁽²⁾	Samp le ID: Date:	C-19-DS-W 04/19/05	C-19-DM-W 04/19/05	C-19-DB-W 04/19/05	C-27-DS-W 05/02/05	C-27-DM-W 05/02/05
Anions (mg/L)								
Chloride	NA	NA		24600	23700	28500	21300	29400
Sulfate	NA	NA		3000	2980	3500	2880	3970
General Analytical (mg/L)								
Ammonia	NA	NA		0.020 U	0.038	0.060	0.020 U	0.026
Biochemical Oxygen Demand	NA	NA		2.0 U	2.0 U	2.0 U	2.0 U	10.7
Chemical Oxygen Demand	NA	NA		890 J	815 J	382 J	701 J	748 J
Colloidal Solids	NA	NA		28.0 J	29.0 J	39.0 J	4.0 U	4.0 U
Non-Filterable Residue (103 C)	NA	NA		28.0 J	29.0 J	39.0 J	10 U	10 U
Total Organic Nitrogen	NA	0.32		0.18	0.10 U	0.17	0.10 U	0.10 U
Total Phosphorous	NA	0.1		0.010 U				
Total Residue (103 C)	NA	NA		26500	27800	28700	536	28000

J = Estimated value.

U = Not detected at the reported value.

mg/L = Milligrams per liter

S - Surface, M - Middle, B - Bottom

NA = Screening criteria not available for this analyte in saline water.

(1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations, June 1998 (2) EPA Office of Water, National Recommended Water Quality Criteria, 2002.

(2) Highlighted values exceed the EPA screening criteria.

Source: Ecology and Environment, Inc 2005

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Table 2-4 Summary of Positive Analytical Results for Water Quality Samples, May 2005

Analyte	NYSDEC Screening Criteria ⁽¹⁾	EPA Screening Criteria ⁽²⁾	Samp le ID: Date:	C-27-DB-W 05/02/05	C-28-DS-W 05/02/05	C-28-DM-W 05/02/05	C-28-DB-W 05/02/05
Anions (mg/L)							
Chloride	NA	NA		30700	25500	32800	25200
Sulfate	NA	NA		4340	3520	4620	3520
General Analytical (mg/L)							
Ammonia	NA	NA		0.020 U	0.020 U	0.020 U	0.026
Biochemical Oxygen Demand	NA	NA		2.0 U	2.0 U	2.0 U	2.0 U
Chemical Oxygen Demand	NA	NA		776 J	611 J	715 J	646 J
Colloidal Solids	NA	NA		11.0	4.0 U	4.0 U	4.0 U
Non-Filterable Residue (103 C)	NA	NA		11.0	10 U	10 U	10 U
Total Organic Nitrogen	NA	0.32		0.10 U	0.10 U	0.10 U	0.10 U
Total Phosphorous	NA	0.1		0.010 U	0.010 U	0.010 U	0.013
Total Residue (103 C)	NA	NA		28200	27100	28300	25600

J = Estimated value.

U = Not detected at the reported value.

mg/L = Milligrams per liter

S - Surface, M - Middle, B - Bottom

NA = Screening criteria not available for this analyte in saline water.

(1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations, June 1998 (2) EPA Office of Water, National Recommended Water Quality Criteria, 2002.

(2) Highlighted values exceed the EPA screening criteria.

Source: Ecology and Environment, Inc 2005

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- Significant coastal fish and wildlife habitats;
- Wild, scenic, and recreational rivers;
- Essential fish habitats (EFHs);
- Drinking water supplies;
- · Special waters of protection; and
- Critical environmental areas.

The proposed Project would overlap with EFHs for several species within Long Island Sound. EFHs include those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. A complete description of EFH within the Project area is presented in Appendix A of Resource Report 3, Fish, Wildlife, and Vegetation.

The Project is located within portions of Long Island Sound identified on the 2004 New York State Section 303(d) list of impaired waters under Section 303(d) of the CWA (NYSDEC 2004). The western Suffolk County waters of Long Island Sound have fish consumption advisories due to the presence of PCBs in striped bass (*Morone saxatilis*). The source of this contamination is unidentified due to the migratory nature of this species. In addition, a TMDL for nitrogen from point and non-point sources is currently in Phase III of implementation for the waters of the Long Island Sound, with final implementation planned for 2014. TMDL requirements are described in Section 2.3.3.

2.3.5 Sediment Transport and Contamination

Sedimentation resulting from Project installation is unavoidable as the pipeline must be installed below the seabed. Broadwater is proposing to minimize impacts through the use of a subsea plow to install the pipeline. Historically used construction methods (dredging or jetting) have tended to introduce larger quantities of sediment into the water column. The subsea plow will essentially push the sediment out of the trench and into adjacent spoil piles.

Circulation in Long Island Sound is controlled by a combination of tidal current and estuarine bottom drift. The Sound primarily consists of an east-to-west decreasing gradient of tidal currents coupled with a westward-directed estuarine bottom drift controlling the regional distribution of sedimentary environments (Knebel and Poppe 2000). As a result of the interaction of these forces, a westward succession of environments begins with erosion or nondeposition at the narrow eastern entrance to the Sound. Sediments in this area are generally coarser, including sandy, silty, and gravelly sands. The east-central portion of the Sound is dominated by an extensive area of coarse-grained bedload transport (*see* Figure 2-5). In the central and western basins of the Sound, the sediments transition into broad areas of finer-grained deposits of sand, clay,

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and silt. The contiguous band of sediment sorting, located between these two areas, is characterized by sand deposits (Knebel and Poppe 2000).

In general, sediment types in the Project area range from a mix of sandy silt and clay to a purely sandy bottom (*see* Figure 2-6). Toward the western end of the Project area, a linear outcrop (Stratford Shoal) containing gravelly sand and bedrock extends in a north-south direction across the Sound. Additional discussions of the existing sedimentary environment in the Sound are provided in Section 2.3.6. As indicated in this section, the sedimentary environment identified through detailed field surveys closely approximates the information presented in the background literature.

Following analysis of the sediment types that occur within the Project area and development of the construction plan for installation of the FSRU and subsea pipeline, sediment transport modeling was conducted to assess the impacts of Project installation. The MIKE3 model was used to assess the extent of sediment transport resulting from construction. The United States Army Corps of Engineers (USACE), NYSDEC, and EPA have all concurred with use of this model to assess sediment transport in the Project area (see Appendix B).

MIKE3 is a 3-dimensional, time-variable, continuous-simulation model that takes Long Island Sound's hydrodynamics into account. The model can determine the fate and transport of sediments and contaminants to determine potential water quality impacts that may result from installation of the Project. In essence, the model treats the installation of the pipeline as a moving point source that releases a mass of solids and particulates and/or dissolved contaminants into specific model cells that overlie the trench. Mass loadings are then used to generate constituent concentrations in the water column, transported by prevailing currents and dispersion patterns.

MIKE 3 is the result of more than 10 years of continuous development and is tuned through the experience gained from many applications worldwide. This model is widely used by the USACE, New York District, to provide a flexible, comprehensive model that can be used to evaluate ongoing USACE projects throughout the New York/New Jersey Harbor and Long Island Sound. Specific model development for use through the New York District was coordinated with a number of federal and state agencies, including the USACE Waterways Experiment Station in Vicksburg, Mississippi; NYSDEC; the New York City Department of Environmental Protection; the New Jersey Department of Environmental Protection; the U.S. Geological Survey (USGS); the National Weather Service; and the National Oceanographic and Atmospheric Administration (NOAA).

2.3.6 Contaminated Sediments

The sediments within the Sound are impacted by a variety of sources, including urban and agricultural runoff, sewage effluent, atmospheric deposition, dredge spoil disposal activities, and industrial discharges. The influence of these sources increases with

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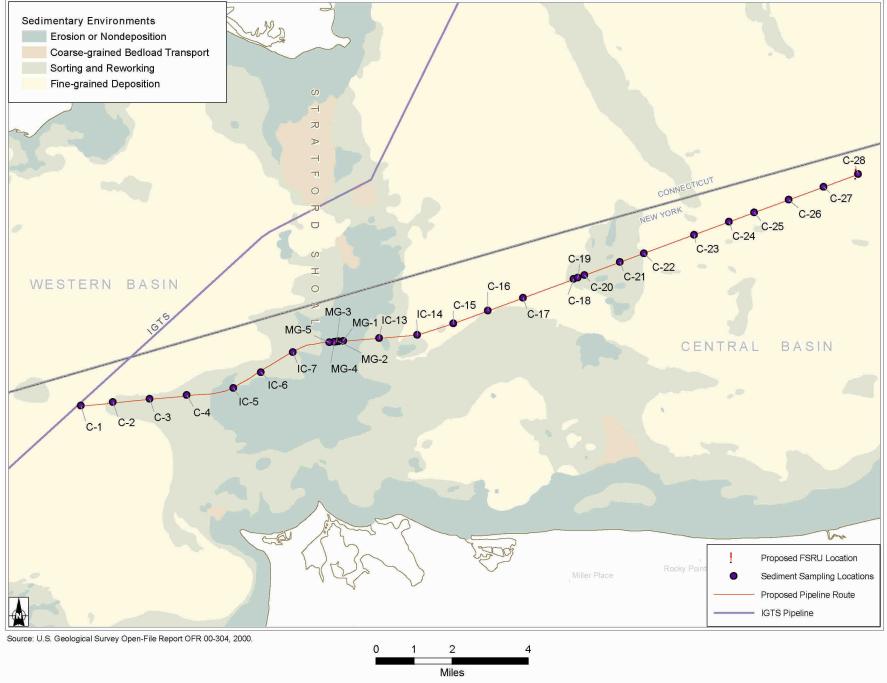
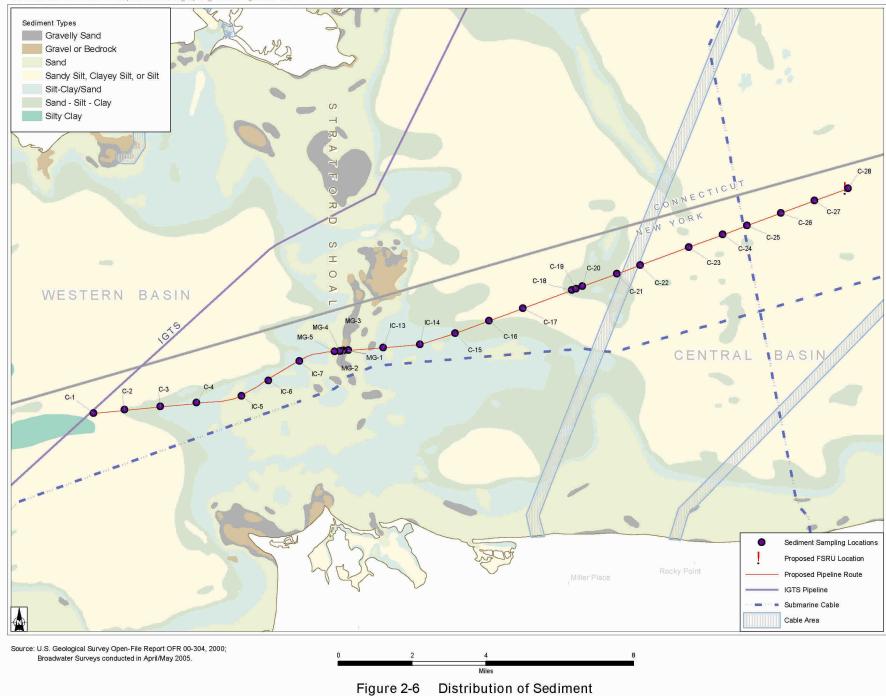


Figure 2-5 Sedimentary Environments



proximity to large urban and agricultural areas. Semi-enclosed marine areas such as Long Island Sound are particularly sensitive to anthropogenic inputs due the potential for less efficient removal, dispersal, and dilution of water and sediments (Buchholtz ten Brink and Mecray 1998).

Based on sediment sampling conducted in the spring of 2005, Broadwater has demonstrated that no elevated contamination levels are present in proximity to the Project area. While existing literature indicates that isolated hot spots may occur in proximity to the proposed pipeline route, field survey results demonstrate that the pipeline alignment has been able to avoid areas with elevated contaminant levels.

The interaction between contaminants in the sedimentary environment is dependent on sediment properties such as a high clay or silt content versus a more gravel or cobble-like texture. Contaminant levels tend to be higher in sediments with high clay or silt content. Contaminants adhere to clay particles more readily than to gravel or cobble and become sequestered as part of the particle complex because the surficial charge on clay particles attracts contaminants. Because gravel or cobble materials do not contain a positively charged surface, contaminants do not adhere as readily to this type of sediment.

Contamination maps obtained from the USGS indicate that contamination within Long Island Sound is generally concentrated in the western portion of the Sound and near highly populated areas. The data pertaining to existing metals concentrations demonstrate a higher contamination load in the western Project area. This is consistent with the historically higher urbanization/development that has occurred in the area. In general, contaminant levels are reduced toward the eastern portion of the Sound. The distribution of sediments with a higher percentage of clay and silt correspond to areas with higher levels of contamination, while the sandier areas correspond to areas with lower contaminant levels. This correspondence is likely due to the physical and chemical properties of the sediments, as certain contaminants tend to adhere more readily to sediments with high clay content. Total organic carbon concentrations, at least partially indicative of pollutant additions, also vary across Long Island Sound, with higher concentrations occurring towards the western end of the Sound (Institute for Sustainable Energy 2003).

The proposed pipeline route lies in the open-water environment of central Long Island Sound. While not as contaminated as the western portions of the Sound, some level of contamination exists. Based on USGS mapping, metals contamination (chromium, lead, mercury, and zinc) is present in areas surrounding the proposed pipeline route (*see* Figures 2-7a through 2-7d). However, the current route placement was chosen to avoid the areas containing the highest levels of contamination identified by the areas shown in red on Figures 2-7a through 2-7d. Data from the New York State Sediment database also was reviewed and compared to USGS mapping. The data points reviewed from the New York State Sediment database are shown on Figure 2-8. Based on this comparison, it was determined that the levels of contamination were of the same magnitude for both data sets, and the level of contamination was similar at the same locations.

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Figure 2-7a USGS Mapped Sediment Contamination of Long Island Sound - Chromium

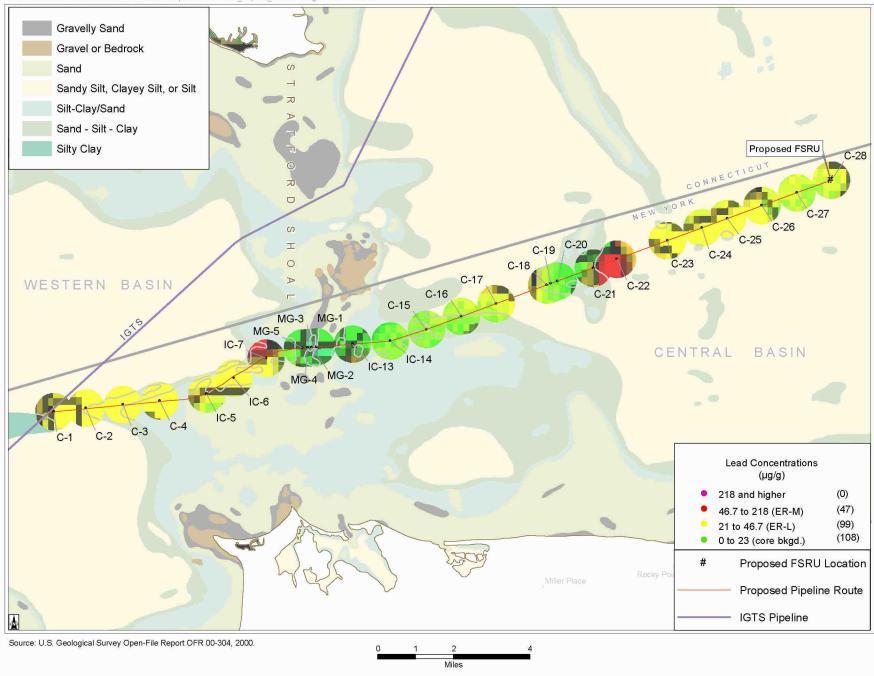


Figure 2-7b USGS Mapped Sediment Contamination of Long Island Sound - Lead

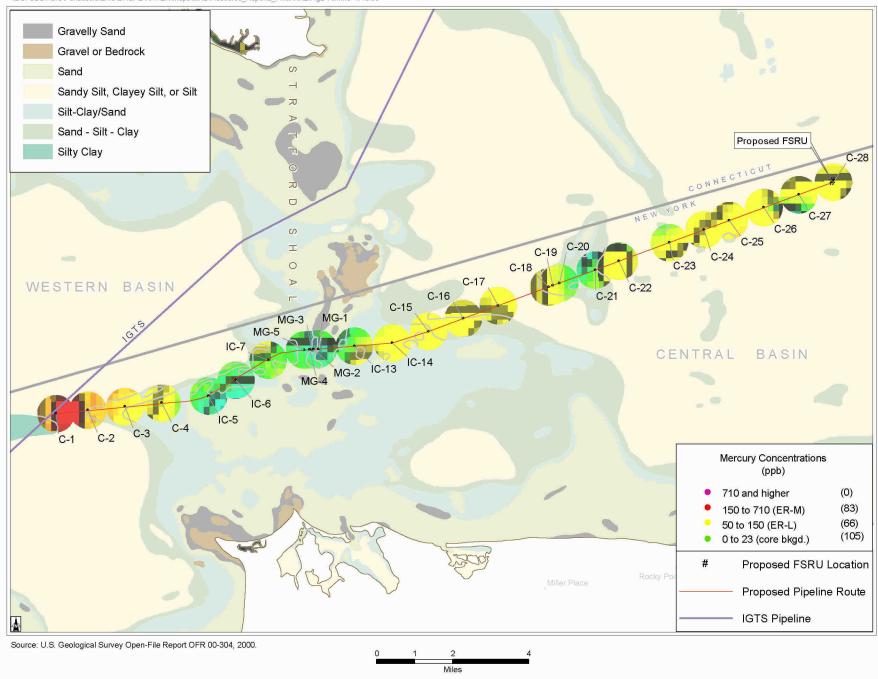


Figure 2-7c USGS Mapped Sediment Contamination of Long Island Sound - Mercury

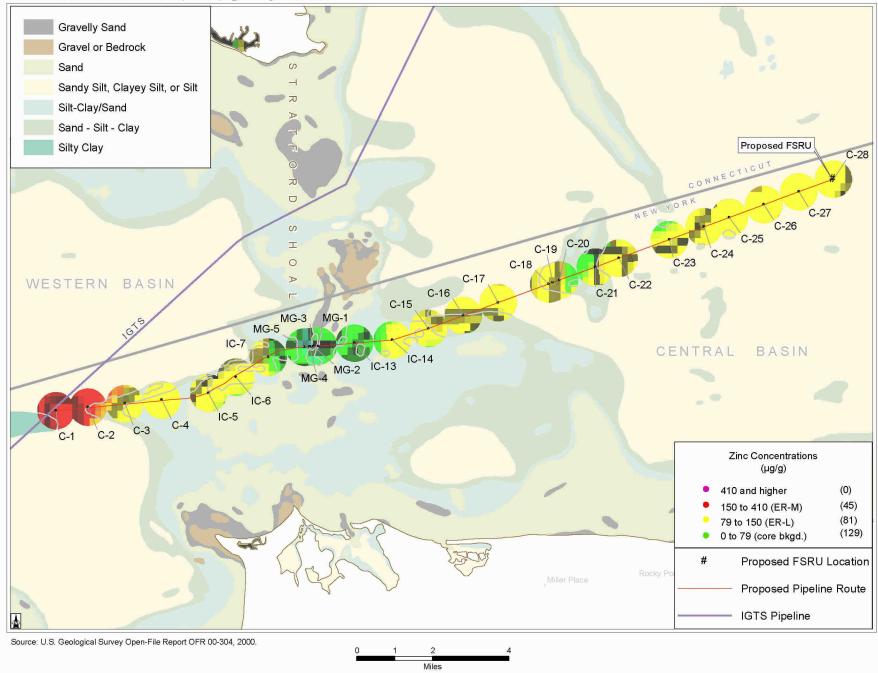


Figure 2-7d USGS Sediment Contamination of Long Island Sound - Zinc

Figure 2-8 NYSDEC Sediment Sampling Locations In Long Island Sound

In addition to metals contamination, other contaminants present in Long Island Sound sediments include polycyclic aromatic hydrocarbons (PAHs) and petroleum-related compounds, various pesticides, polychlorinated biphenyls (PCBs), and dioxins.

Field Sampling Results

A sediment sampling plan was developed to evaluate the site-specific sediment conditions along the proposed pipeline route. The plan included analysis for several different contaminants at an interval of one sediment sample per mile along the proposed pipeline route, with adjustments to shorten or lengthen the interval applied to account for changes in sediment type, which may be indicative of changes in the level of potential contamination (*see* Figure 2-8). Sediment sampling was performed through a coring operation in which a 10-foot (3.3 m) sediment core was collected from each sample location using a vibracore unit mounted on a 100-foot (33.3 m) sample vessel. Once retrieved, the sediment core soil types were classified, and sediment samples were collected from the core and shipped to a laboratory for chemical analysis. The tests performed, method, and numbers of samples collected are summarized in Table 2-5.

Table 2-5 Summary of Sediment Chemical Analysis

Test Description	EPA Method Number	Number of Samples Collected
Arsenic as TCL Metals	EPA 6010B	28
Cadmium as TCL Metals	EPA 6010B	28
Copper as TCL Metals	EPA 6010B	28
Lead as TCL Metals	EPA 6010B	28
Mercury	EPA 6010B	28
Benzene	EPA 8021B or 8260B	28
Total BTX	EPA 8021B or 8260B	28
Total PAH (Sum of Target Compound List PAH)	EPA 8270C	28
Sum of DDT+DDE+DDD	EPA 8081A	28
Mirex	EPA 8081A	28
Chlordane	EPA 8081A	28
Dieldrin	EPA 8081A	28
PCBs (sum of aroclors)	EPA 8082	28
Dioxin (Toxicity Equivalency Total calculated from PCDD/PCDF congeners)	EPA 1613B	8
Total Organic Carbon (TOC)	Lloyd Kahn	28

Once the laboratory analysis was completed, data package results were received and data was put through a rigorous quality assurance/quality control (QA/QC) program according to NYSDEC ASP requirements. Upon completion of the QA/QC review, positive results were evaluated and compared to available criteria from NYSDEC, Division of Water, *Technical and Operational Guidance Series (TOGS) 5.1.9 for In-Water and Riparian Management of Sediment and Dredged Material* (November 2004) as well as NYSDEC,

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Division of Fish, Wildlife and Marine Resources, *Technical Guidance for Screening Contaminated Sediments, Effects Range-Low and Effects Range-Median* (January 1999). The comparison of these criteria is presented below in Tables 2-6 and 2-7.

Metals

Positive results for metals included identification of several analytes on the target compound list that were present in every sediment sample (*see* Table 2-6). The Effects Range-Low (ER-L) value was exceeded for iron in five samples and manganese in two samples. However, none of the metals detected exceeded the TOGS criteria. Subsequent to submittal of the draft Environmental Sampling Report (E & E 2005) to NYSDEC, NYSDEC questioned the omission of cadmium in the sediment results. As presented to NYSDEC (*see* Appendix C), cadmium and several other metals were not included in the table of positive analytical results because they were not detected in the laboratory analyses.

Polycyclic Aromatic Hydrocarbons (PAH)

PAHs were not detected in any of the sediment samples collected along the proposed pipeline route.

Pesticides

Pesticides were not detected in any of the sediment samples collected along the proposed pipeline route.

Polychlorinated Biphenyls (PCBs)

PCBs were not detected in any of the sediment samples collected along the proposed pipeline route.

Volatile Organic Compounds

Positive results for VOCs included identification of acetone in sample C-24 and identification of dichlorodifluoromethane in sample C-3D. However, these contaminants are likely attributable to sample handling procedures. Positive results for VOCs also included identification of toluene in all but four samples. Toluene values ranged from 0.001 mg/kg to 0.13 mg/kg; however, none of these values exceed the TOGS criteria for toluene of 0.96 mg/kg.

Dioxin

Positive results for dioxin analysis included identification of some PCDD (dioxin) and PCDF (furan) congeners in samples that were collected from a discrete depth interval in the sediment core. Discrete depth interval sampling for dioxin was implemented as part of the sediment sampling program in order to target the area of highest clay content in the sediment cores that were analyzed for dioxin. The areas of highest clay content were identified for analysis since dioxins and other contaminants adhere to sediments with a

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Table 2-6 Summary of Positive Analytical Results for Sediment Samples, May 2005

Analyte	Screening Criteria ^{(1) -} ERL	Screening Criteria ^{(1) -} ERM	Sample ID: Date:	C-1 04/29/05	C-2 04/22/05	C-3 04/28/05	C-3D 04/28/05	C-4 04/22/05
Volatiles (ppm)								
Acetone	NA	NA		0.025 U	0.023 U	0.025 U	0.025 U	0.025 U
Dichlorodifluoromethane	NA	NA		0.0050 U	0.0050 U	0.0050 U	0.0010 J	0.0050 U
Toluene	0.96	0.96		0.0030 J	0.013	0.0040 J	0.054	0.027
Metals (ppm)								
Aluminum - Total	NA	NA		7500	5670	7550	4900	7900
Arsenic - Total	8.2	70		5.4	2.4 J	3.6	4.3	5.0 J
Barium - Total	NA	NA		23.7 J	15.9 J	22.6 J	14.8 J	23.6 J
Beryllium - Total	NA	NA		0.39	0.30	0.40	0.25	0.40
Calcium - Total	NA	NA		2350 J	1200 J	2070 J	1410 J	2950 J
Chromium - Total	81	370		16.3	12.0 J	16.0	12.2	26.5 J
Cobalt - Total	NA	NA		6.5	4.1 J	6.3	4.8	7.0 J
Copper - Total	33	270		8.1	4.6 J	7.8	10.6	28.8 J
Iron - Total	20000	40000		15100 J	10000	14600 J	9480 J	15300
Lead - Total	47	218		5.9	3.7	5.7	6.5	18.6
Magnesium - Total	NA	NA		5500 J	3730 J	5460 J	3360 J	5490 J
Manganese - Total	460	1100		409 J	175	326 J	214 J	419
Sodium - Total	NA	NA		5750	4660 J	4940	3120	5710 J
Nickel - Total	20.9	51.6		11.8	8.3 J	11.9	8.8	13.4 J
Potassium - Total	NA	NA		2640	1970 J	2580	1550	2580 J
Vanadium - Total	NA	NA		22.5 J	14.3 J	22.9 J	14.8 J	21.6 J
Zinc - Total	150	410		33.5	23.1 J	34.3	30.4	70.7 J
Mercury - Total	0.17	0.71		0.016 U	0.011 U	0.026	0.063	0.040
Total Organic Carbon (ppm)								
Total Organic Carbon	NA	NA		14000	7920	6370	7950	6940

J = Estimated value.

U = Not detected at the reported value.

ppm = parts per million

NA = Screening critiera not available for this analyte.

- (1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Technical Guidance for Screening Contaminated Sediment (Effects Range Low/Effects Range Median), January 1999. Instances where a TOGS value was not available, the screening criteria was supplemented with ERL/ERM values.
- (2) Note that 5 metals are not reported in this table since there were no positive results for these analytes in any sediment sample analyzed. These metals include: antimony, cadmium, selenium, silver, and thallium. See Appendix I for additional details.
- (3) Highlighted values exceed EPA screening critieria.

Table 2-6 Summary of Positive Analytical Results for Sediment Samples, May 2005

Analyte	Screening Criteria ^{(1) -} ERL	Screening Criteria ^{(1) -} ERM	Sample ID: Date:	C-4D 04/22/05	IC-5 04/29/05	IC-6 04/27/05	IC-7 04/27/05	MG-5 04/21/05
Volatiles (ppm)								
Acetone	NA	NA		0.021 U	0.024 U	0.021 U	0.024 U	0.022 U
Dichlorodifluoromethane	NA	NA		0.0040 U	0.0050 U	0.0040 U	0.0050 U	0.0040 U
Toluene	0.96	0.96		0.0010 J	0.049	0.022	0.0040 J	0.010
Metals (ppm)								
Aluminum - Total	NA	NA		6960	7880	4090	5820	1840
Arsenic - Total	8.2	70		5.2 J	5.6	3.0 J	3.7 J	1.2 J
Barium - Total	NA	NA		21.4 J	21.0	12.7 J	29.6 J	4.2 J
Beryllium - Total	NA	NA		0.36	0.42	0.21 J	0.29 J	0.11 U
Calcium - Total	NA	NA		2570 J	4540	1680	6230	725 J
Chromium - Total	81	370		15.4 J	17.8	8.3 J	11.6 J	5.0 J
Cobalt - Total	NA	NA		6.4 J	8.5	4.3 J	5.9 J	1.7 J
Copper - Total	33	270		9.0 J	11.2	3.5 J	10.3 J	5.8 J
Iron - Total	20000	40000		13800	16800	8000	11800	3790
Lead - Total	47	218		6.2	8.1	3.1 J	4.6 J	3.7
Magnesium - Total	NA	NA		5200 J	5370	2830	4100	1180 J
Manganese - Total	460	1100		312	284	163	377	60.4
Sodium - Total	NA	NA		4690 J	5270	2810	4330	2070 J
Nickel - Total	20.9	51.6		11.4 J	14.3	7.1 J	10.4 J	3.2 J
Potassium - Total	NA	NA		2240 J	2860	1340 J	1650 J	639 J
Vanadium - Total	NA	NA		18.5 J	22.0	11.2 J	16.6 J	5.5 J
Zinc - Total	150	410		34.5 J	43.7	18.1 J	28.0 J	15.5 J
Mercury - Total	0.17	0.71		0.021	0.014	0.011 U	0.017 U	0.012 U
Total Organic Carbon (ppm)								
Total Organic Carbon	NA	NA		8640	4330	4310	7040	665

J = Estimated value.

U = Not detected at the reported value.

ppm = parts per million

NA = Screening critiera not available for this analyte.

- (1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Technical Guidance for Screening Contaminated Sediment (Effects Range Low/Effects Range Median), January 1999. Instances where a TOGS value was not available, the screening criteria was supplemented with ERL/ERM values.
- (2) Note that 5 metals are not reported in this table since there were no positive results for these analytes in any sediment sample analyzed. These metals include: antimony, cadmium, selenium, silver, and thallium. See Appendix I for additional details.
- (3) Highlighted values exceed EPA screening critieria.

Table 2-6 Summary of Positive Analytical Results for Sediment Samples, May 2005

Analyte	Screening Criteria ^{(1) -} ERL	Screening Criteria ^{(1) -} ERM	Sample ID: Date:	MG-3 04/20/05	IC-13 04/30/05	IC-14 04/30/05	C-15 04/26/05	C-16 04/26/05
Volatiles (ppm)								
Acetone	NA	NA		0.023 U	0.024 U	0.024 U	0.023 U	0.025 U
Dichlorodifluoromethane	NA	NA		0.0040 U	0.0050 U	0.0050 U	0.0040 U	0.0050 U
Toluene	0.96	0.96		0.0080	0.0020 J	0.0040 J	0.0060	0.0030 J
Metals (ppm)								
Aluminum - Total	NA	NA		2840	5180	12000	5240 J	6810 J
Arsenic - Total	8.2	70		1.3 U	4.6	6.4	4.2	5.9
Barium - Total	NA	NA		9.8 J	13.8	35.2	15.3	18.8
Beryllium - Total	NA	NA		0.14	0.30	0.60	0.26	0.33
Calcium - Total	NA	NA		704 J	3520	4230	1700 J	2580 J
Chromium - Total	81	370		5.5 J	14.0	27.5	14.2	14.5
Cobalt - Total	NA	NA		1.6 J	5.3	11.7	4.4	5.9
Copper - Total	33	270		6.4 J	10.9	15.6	18.3	6.2
Iron - Total	20000	40000		4230	10900	23800	10000 J	13900 J
Lead - Total	47	218		2.4	7.7	11.0	9.6	4.6
Magnesium - Total	NA	NA		1200 J	3370	8740	3500 J	4900 J
Manganese - Total	460	1100		51.3	186	546	175 J	244 J
Sodium - Total	NA	NA		1730 J	5190	7770	3680	4550
Nickel - Total	20.9	51.6		3.9 J	8.1	18.6	8.6	11.1
Potassium - Total	NA	NA		843 J	1940	4000	1670 J	2220 J
Vanadium - Total	NA	NA		7.0 J	18.0	32.5	14.1	18.4
Zinc - Total	150	410		11.2 J	34.4	62.1	41.5	28.9
Mercury - Total	0.17	0.71		0.012 U	0.012	0.015	0.036	0.020
Total Organic Carbon (ppm)								
Total Organic Carbon	NA	NA		644 U	1640	3990	7690	9510

J = Estimated value.

U = Not detected at the reported value.

ppm = parts per million

NA = Screening critiera not available for this analyte.

- (1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Technical Guidance for Screening Contaminated Sediment (Effects Range Low/Effects Range Median), January 1999. Instances where a TOGS value was not available, the screening criteria was supplemented with ERL/ERM values.
- (2) Note that 5 metals are not reported in this table since there were no positive results for these analytes in any sediment sample analyzed. These metals include: antimony, cadmium, selenium, silver, and thallium. See Appendix I for additional details.
- (3) Highlighted values exceed EPA screening critieria.

Table 2-6 Summary of Positive Analytical Results for Sediment Samples, May 2005

Analyte	Screening Criteria ^{(1) -} ERL	Screening Criteria ^{(1) -} ERM	Sample ID: Date:	C-16D 04/26/05	C-17 04/24/05	C-18 04/19/05	C-19 04/19/05	C-20 04/21/05
Volatiles (ppm)								
Acetone	NA	NA		0.025 U	0.025 U	0.029 U	0.025 U	0.024 U
Dichlorodifluoromethane	NA	NA		0.0050 U	0.0050 U	0.0060 U	0.0050 U	0.0050 U
Toluene	0.96	0.96		0.0060	0.0080	0.075	0.016	0.0050
Metals (ppm)								
Aluminum - Total	NA	NA		8360 J	8030 J	1230	1630	2940
Arsenic - Total	8.2	70		7.6	4.8	1.3 U	1.2 U	2.3 J
Barium - Total	NA	NA		23.2	22.5 J	3.5 J	5.7 J	8.0 J
Beryllium - Total	NA	NA		0.42	0.42	0.13 U	0.14	0.17
Calcium - Total	NA	NA		2650 J	2520 J	241 J	540 J	783 J
Chromium - Total	81	370		18.3	18.2	2.6 J	4.3 J	8.4 J
Cobalt - Total	NA	NA		6.7	5.9	1.6	1.9	2.9 J
Copper - Total	33	270		11.7	9.1	2.7	3.4	7.8 J
Iron - Total	20000	40000		16300 J	14900 J	3290 J	4170 J	7100
Lead - Total	47	218		7.4	6.5	2.2	2.3	4.2
Magnesium - Total	NA	NA		5560 J	5190 J	790	876	1760 J
Manganese - Total	460	1100		249 J	246 J	35.3 J	51.5 J	78.7
Sodium - Total	NA	NA		6010	5820	1860	2980	2110 J
Nickel - Total	20.9	51.6		13.6	12.6	2.6	2.8	5.5 J
Potassium - Total	NA	NA		2700 J	2680 J	288	505	940 J
Vanadium - Total	NA	NA		23.1	21.7	6.2	9.3	9.2 J
Zinc - Total	150	410		42.5	37.1	5.6	9.5	20.3 J
Mercury - Total	0.17	0.71		0.017 U	0.016 U	0.011 U	0.010 U	0.012
Total Organic Carbon (ppm)								
Total Organic Carbon	NA	NA		9910	11100	10400	7100	2440

J = Estimated value.

U = Not detected at the reported value.

ppm = parts per million

NA = Screening critiera not available for this analyte.

- (1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Technical Guidance for Screening Contaminated Sediment (Effects Range Low/Effects Range Median), January 1999. Instances where a TOGS value was not available, the screening criteria was supplemented with ERL/ERM values.
- (2) Note that 5 metals are not reported in this table since there were no positive results for these analytes in any sediment sample analyzed. These metals include: antimony, cadmium, selenium, silver, and thallium. See Appendix I for additional details.
- (3) Highlighted values exceed EPA screening critieria.

Source: Ecology and Environment, Inc

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Table 2-6 Summary of Positive Analytical Results for Sediment Samples, May 2005

Analyte	Screening Criteria ^{(1) -} ERL	Screening Criteria ^{(1) -} ERM	Sample ID: Date:	C-21 05/01/05	C-22 05/01/05	C-23 05/03/05	C-24 05/03/05	C-25 05/04/05
Volatiles (ppm)								
Acetone	NA	NA		0.024 U	0.024 U	0.025 U	0.022 J	0.025 U
Dichlorodifluoromethane	NA	NA		0.0050 U				
Toluene	0.96	0.96		0.020	0.13	0.0050 U	0.0050	0.0020 J
Metals (ppm)								
Aluminum - Total	NA	NA		6730	12400	12000	11500	11900
Arsenic - Total	8.2	70		3.6	7.1	5.4	6.5	6.3
Barium - Total	NA	NA		12.6	36.7	34.4	32.8	34.0
Beryllium - Total	NA	NA		0.33	0.66	0.58	0.55	0.59
Calcium - Total	NA	NA		1880	7040	3820	3780	3220
Chromium - Total	81	370		11.6	29.2	27.3	24.6	25.6
Cobalt - Total	NA	NA		6.7	10.9	8.1	7.9	8.0
Copper - Total	33	270		15.1	13.9	14.4	12.0	10.6
Iron - Total	20000	40000		13600	24900	21000	20200	21000
Lead - Total	47	218		9.8	11.7	9.7	7.7	7.4
Magnesium - Total	NA	NA		4010	9220	7640	7090	7500
Manganese - Total	460	1100		167	475	329	324	291
Sodium - Total	NA	NA		3990	7870	8440	8370	8840
Nickel - Total	20.9	51.6		10.8	18.0	17.9	17.4	17.6
Potassium - Total	NA	NA		1780	4460	3990	3820	4100
Vanadium - Total	NA	NA		22.2	34.4	30.6	30.9	30.2
Zinc - Total	150	410		36.4	57.4	53.9	46.6	47.6
Mercury - Total	0.17	0.71		0.011 U	0.012 U	0.022	0.016 U	0.019 U
Total Organic Carbon (ppm)								
Total Organic Carbon	NA	NA		2910	12400	11100	10700	9780

J = Estimated value.

U = Not detected at the reported value.

ppm = parts per million

NA = Screening critiera not available for this analyte.

- (1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Technical Guidance for Screening Contaminated Sediment (Effects Range Low/Effects Range Median), January 1999. Instances where a TOGS value was not available, the screening criteria was supplemented with ERL/ERM values.
- (2) Note that 5 metals are not reported in this table since there were no positive results for these analytes in any sediment sample analyzed. These metals include: antimony, cadmium, selenium, silver, and thallium. See Appendix I for additional details.
- (3) Highlighted values exceed EPA screening critieria.

Table 2-6 Summary of Positive Analytical Results for Sediment Samples, May 2005

Analyte	Screening Criteria ^{(1) -} FRI	Screening Criteria ^{(1) -} ERM	Sample ID: Date:	C-26 05/03/05	C-27 05/02/05	C-28 05/02/05
Volatiles (ppm)	Jinoila Litt	C.I.GIIG EIGH	24.01	30,00,00		55,52,66
Acetone	NA	NA		0.024 U	0.023 U	0.023 U
Dichlorodifluoromethane	NA	NA		0.0050 U	0.0050 U	0.0050 U
Toluene	0.96	0.96		0.0050 U	0.0050 U	0.0050 U
Metals (ppm)						
Aluminum - Total	NA	NA		11000	10700	10700
Arsenic - Total	8.2	70		6.9	6.7	7.1
Barium - Total	NA	NA		33.1	31.7	30.4
Beryllium - Total	NA	NA		0.54	0.52	0.50
Calcium - Total	NA	NA		2680	2830	3600
Chromium - Total	81	370		24.8	23.3	23.1
Cobalt - Total	NA	NA		7.7	7.6	7.3
Copper - Total	33	270		12.4	10.4	13.2
Iron - Total	20000	40000		20000	19900	18800
Lead - Total	47	218		8.5	6.7	8.1
Magnesium - Total	NA	NA		6910	6690	6500
Manganese - Total	460	1100		308	272	268
Sodium - Total	NA	NA		7910	6670	7510
Nickel - Total	20.9	51.6		16.9	16.3	16.1
Potassium - Total	NA	NA		3790	3570	3450
Vanadium - Total	NA	NA		28.6	28.3	27.0
Zinc - Total	150	410		48.1	44.2	47.0
Mercury - Total	0.17	0.71		0.017 U	0.015 U	0.017 U
Total Organic Carbon (ppm)						
Total Organic Carbon	NA	NA		10400	10000	8260

J = Estimated value.

U = Not detected at the reported value.

ppm = parts per million

NA = Screening critiera not available for this analyte.

- (1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004 and NYSDEC Technical Guidance for Screening Contaminated Sediment (Effects Range Low/Effects Range Median), January 1999. Instances where a TOGS value was not available, the screening criteria was supplemented with ERL/ERM values.
- (2) Note that 5 metals are not reported in this table since there were no positive results for these analytes in any sediment sample analyzed. These metals include: antimony, cadmium, selenium, silver, and thallium. See Appendix I for additional details.
- (3) Highlighted values exceed EPA screening critieria.

Table 2-7 Summary of Positive Analytical Results for Dioxin in Sediment Samples, May 2005

	Saraaning	Sample ID:	C-1-D3-4	C-4-D2-3	C-4D-D2-3	IC-7-D2-3	IC-13-D0-1
Analyte	Screening Criteria ⁽¹⁾	Sample ID: Date:	04/29/05	04/22/05	04/22/05	04/27/05	04/30/05
SM1613B (ppm)							
1,2,3,7,8-PeCDD	NA		0.0000050 U	0.00000024 J	0.0000050 U	0.00000027 J	0.00000041 J
1,2,3,4,7,8-HxCDD	NA		0.00000010 J	0.00000024 J	0.0000050 U	0.0000050 U	0.00000060 J
1,2,3,6,7,8-HxCDD	NA		0.0000050 U	0.0000050 U	0.0000050 U	0.00000059 J	0.0000014 J
1,2,3,7,8,9-HxCDD	NA		0.0000050 U	0.00000072 J	0.0000050 U	0.0000011 J	0.0000016 J
1,2,3,4,6,7,8-HpCDD	NA		0.0000026 J	0.0000084 J	0.0000027 J	0.000017	0.000029
OCDD	NA		0.000057 J	0.00021 J	0.000065 J	0.00041 J	0.00032 J
2,3,7,8-TCDF	NA		0.00000030 J	0.0000010 U	0.0000010 U	0.00000015 J	0.0000034
1,2,3,7,8-PeCDF	NA		0.0000050 U	0.0000050 U	0.0000050 U	0.0000050 U	0.0000014 J
2,3,4,7,8-PeCDF	NA		0.0000050 U	0.0000050 U	0.0000050 U	0.0000050 U	0.0000014 J
1,2,3,4,7,8-HxCDF	NA		0.0000050 U	0.0000050 U	0.0000050 U	0.00000014 J	0.0000021 J
1,2,3,6,7,8-HxCDF	NA		0.0000050 U	0.0000050 U	0.0000050 U	0.000000094 J	0.00000096 J
2,3,4,6,7,8-HxCDF	NA		0.0000050 U	0.00000010 J	0.0000050 U	0.0000050 U	0.0000010 J
1,2,3,4,6,7,8-HpCDF	NA		0.0000050 U	0.0000050 U	0.0000050 U	0.0000012 J	0.000015 J
1,2,3,4,7,8,9-HpCDF	NA		0.0000050 U	0.0000050 U	0.0000050 U	0.0000050 U	0.00000080 J
OCDF	NA		0.000010 U	0.000010 U	0.000010 U	0.000010 U	0.000033 J
Dioxin(Toxic Equivalency Total)	0.0000045		0.000000123	0.00000052	0.000000092	0.0000009344	0.000002882

J = Estimated value.

U = Not detected at the reported value.

ppm = parts per million

D - discrete depth interval for sample collection

(1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004

Table 2-7 Summary of Positive Analytical Results for Dioxin in Sediment Samples, May 2005

	Screening	Sample ID:	C-20-D0-1	C-24-D5-6	C-28-D2-3	ENV-3-D1-3	ENV-3D-D1-3
Analyte	Criteria (1)	Date:	04/20/05	05/03/05	05/02/05	04/17/05	04/17/05
SM1613B (ppm)							
1,2,3,7,8-PeCDD	NA		0.0000050 U	0.0000050 U	0.0000050 U	0.000000070 U	0.000000065 U
1,2,3,4,7,8-HxCDD	NA		0.0000050 U	0.00000023 J	0.00000019 J	0.00000010 U	0.000000068 U
1,2,3,6,7,8-HxCDD	NA		0.00000054 J	0.00000040 J	0.00000028 J	0.000000097 U	0.000000066 U
1,2,3,7,8,9-HxCDD	NA		0.00000098 J	0.00000097 J	0.00000079 J	0.00000010 U	0.000000067 U
1,2,3,4,6,7,8-HpCDD	NA		0.000013	0.000017	0.0000095	0.000011 J	0.0000045 J
OCDD	NA		0.00018 J	0.00040 J	0.00025	0.00026 J	0.000095 J
2,3,7,8-TCDF	NA		0.0000010 U	0.0000010 U	0.0000010 U	0.00000016 U	0.00000013 U
1,2,3,7,8-PeCDF	NA		0.00000029 J	0.0000050 U	0.0000050 U	0.000000070 U	0.000000065 U
2,3,4,7,8-PeCDF	NA		0.00000048 J	0.0000050 U	0.0000050 U	0.000000064 U	0.000000057 U
1,2,3,4,7,8-HxCDF	NA		0.00000060 J	0.0000050 U	0.0000050 U	0.000000070 U	0.000000047 U
1,2,3,6,7,8-HxCDF	NA		0.00000053 J	0.0000050 U	0.0000050 U	0.000000068 U	0.000000045 U
2,3,4,6,7,8-HxCDF	NA		0.00000033 J	0.0000050 U	0.0000050 U	0.000000080 U	0.000000050 U
1,2,3,4,6,7,8-HpCDF	NA		0.0000044 J	0.0000012 J	0.00000081 J	0.000000099 U	0.000000074 U
1,2,3,4,7,8,9-HpCDF	NA		0.00000039 J	0.0000050 U	0.0000050 U	0.00000013 U	0.000000098 U
OCDF	NA		0.000010 J	0.000010 U	0.0000014 J	0.00000015 U	0.000000077 U
Dioxin(Toxic Equivalency Total)	0.0000045		0.0000009204	0.000000742	0.0000004805	0.00000037	0.0000014

J = Estimated value.

U = Not detected at the reported value.

ppm = parts per million

D - discrete depth interval for sample collection

(1) New York State Department of Environmental Conservation, Technical and Operational Guidance Series (TOGS) 5.1.9, In-Water and Riparian Management of Sediment and Dredged Material, November 2004

high clay content more readily that sands, gravel, and coarser-grained sediments. However, none of the dioxin and furan results resulted in a toxicity equivalency (TEQ) for 2, 3, 7, 8-TCDD that exceeds the TOGS criteria.

Elevated Nutrient Inputs

Bacteria levels, specifically the levels of *Clostridium perfringens*, can also be viewed representatively as correlating to the elevated nutrient inputs in depositional areas that may be susceptible to sedimentation and the accumulation of contaminated sediments. This bacterium functions as a tracer and indicator of sewage input, which can be a significant source of metal pollutants. The spores of the *Clostridium* are inert in most temperate marine sediments, as both anoxia and elevated temperatures are required for significant growth. Therefore, the presence of *Clostridium* spores in sediments provides a record of sewage input into an ecosystem. The concentrations of *Clostridium perfringens* within Long Island Sound range from non-detectable to approximately 15,000 spores per gram of dry sediment (Buchholtz ten Brink et al. 2000). The highest values occur in the west and west-central portions of the Sound (*see* Figure 2-9). The east-central and eastern portions have low and very low concentrations, respectively.

In order to evaluate bacteria levels along the proposed pipeline route that may be indicative of increased sewage inputs or elevated nutrient inputs, Broadwater collected water quality samples for fecal coliform and total coliform bacteria during the spring 2005 field season. The total coliform bacteria test is a primary indicator of "potability," or suitability as drinking water. The test measures the concentration of total coliform bacteria, which can indicate the possible presence of disease-causing organisms.

Water quality samples were collected from eight locations (C-1, C-3, IC-6, MG-5, C-15, C-19, C-27, and C-28) along the proposed pipeline route. Figure 2-10 indicates the location of the water quality sampling locations. The field effort included collection of water quality samples from three discrete depths at each location. The discrete depths were defined as a sample just below the water surface (<5 feet [1.5 m]), at the midpoint of the water column, and a bottom water column sample (5 feet [1.5 m] from the bottom).

Samples were collected in 1-liter volumes from each of the discrete depths and, due to the short sample storage time, sent to the laboratory on the same day as sample collection for immediate analysis of total and fecal coliform. Analysis of the samples collected from all depths resulted in no detectable fecal coliform or total coliform units. Results for all locations were <1.1 coliform units/100 ml, which is the measurable limit for the presence of the coliform bacteria. The data indicate that the Long Island Sound waters in the Project area are not impacted by sewage or nutrient inputs from the surrounding areas.

2.4 VARIANCES TO THE FERC PROCEDURES

Broadwater's Wetland and Water Body Construction and Mitigation Procedures will include the FERC procedures with the following variances.

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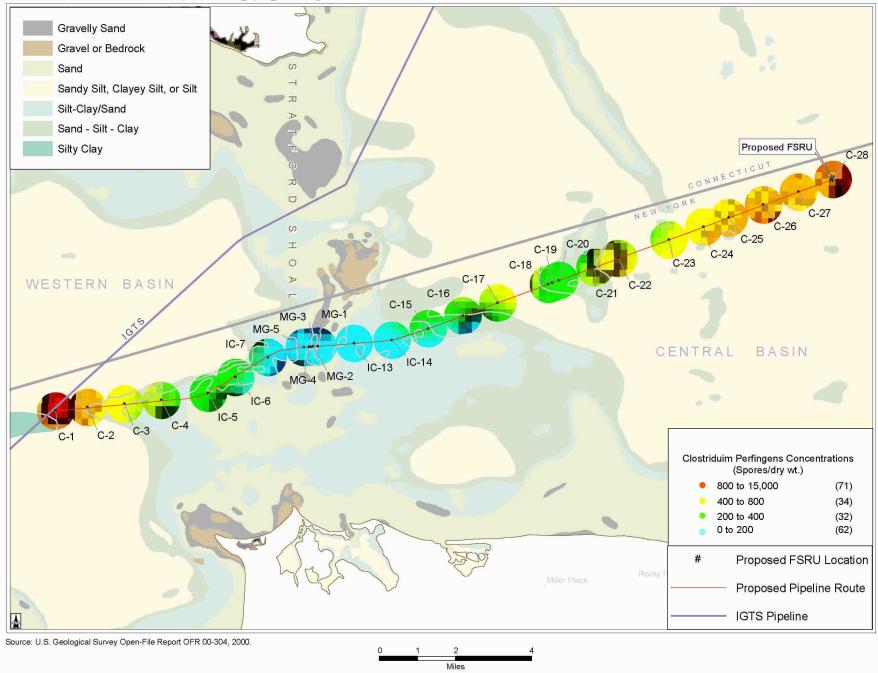


Figure 2-9 USGS Mapped Sediment Contamination of Long Island Sound - Clostridium

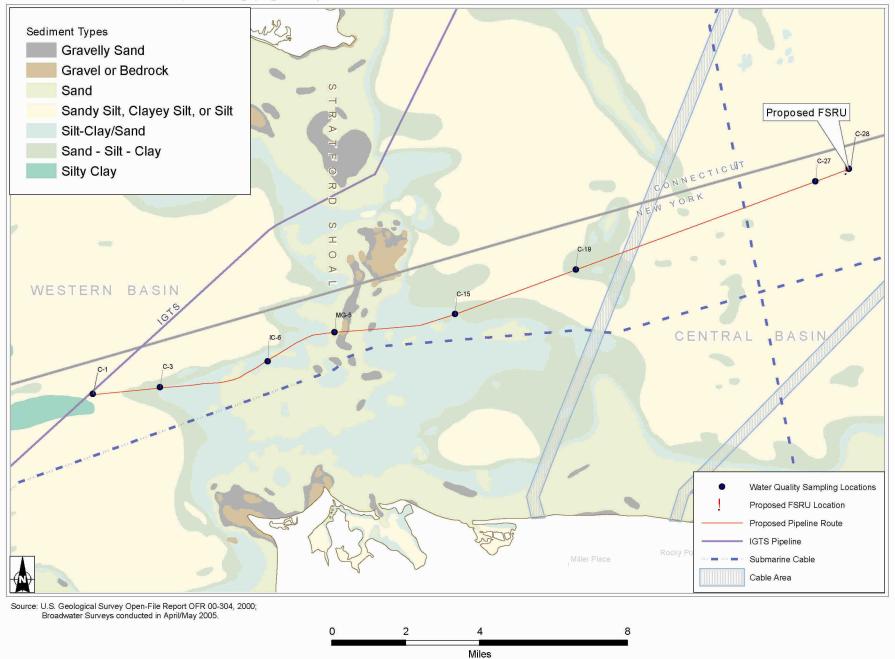


Figure 2-10 Water Quality Sample Locations Spring 2005 Field Survey

Variances to the FERC Procedures

IV A.1.d. Equipment Parking and Fueling

The marine activities associated with construction of the marine pipeline and installation of the tower that will be used to moor the FSRU and secure the send-out pipeline will occur on a 24-hour basis. As such, some refueling of equipment will occur on-water due to the infeasibility of returning to shore to conduct these operations. Broadwater will prepare a Project-specific Spill Prevention Control and Countermeasure (SPCC) plan to address potential spills of fuels and hazardous materials.

IV A.1.e. Storage of Hazardous Materials

To ensure efficient operations, Broadwater will be required to store chemicals, fuels, and lubricating oils on the specific lay barges used during construction. Broadwater will prepare a Project-specific SPCC plan to address potential spills of fuels and hazardous materials.

V B.1 Time Window for Construction

The construction period for the proposed marine pipeline is anticipated to begin in October 2009 and end in April 2010. Installation of the stationary tower structure that will be used to moor the FSRU and secure the send-out pipeline is anticipated to occur in the late summer/fall of 2010. It is anticipated the facility would be operational by the end of 2010. The proposed Project schedule has been developed to avoid the most sensitive biological time windows recognized in the Sound.

2.5 POTENTIAL IMPACTS ON WATER QUALITY

Construction and operation of the proposed facilities have the potential to result in impacts on water quality in the Project area within Long Island Sound. However, impacts during construction are expected to be minor, localized, and short term. Impacts associated with operation will be minor but long-term and result from routine intake and discharge of Sound waters by the FSRU. Impacts have been minimized by siting the facility in the central basin of the Sound, away from shoreline or nearshore areas that contain sensitive waters, and by eliminating the discharge of any contaminants that will impair the waters of the Sound. Utilizing appropriate installation technologies will also minimize any impacts from sediment transport and deposition during pipeline installation and best management practices will be employed on the FSRU during operation to minimize the possibility for any spills to occur that would impact Sound waters.

2.5.1 Construction

2.5.1.1 **Pipeline**

Construction of the proposed pipeline will result in temporary, localized impacts on water quality along the approximately 300–foot (91–m) -wide pipeline corridor, centered on the pipeline trench and adjacent spoil piles, which will encompass a width of approximately 75 feet (23 m). In addition to unavoidable sediment resuspension/redeposition resulting

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from pipeline trenching activities, accidental fuel or oil spills from construction equipment and the discharge of hydrostatic test waters also have the potential to result in impacts. Broadwater has prepared a generic Spill Prevention, Control, and Countermeasures (SPCC) Plan that addresses the potential for spills from equipment utilized during construction and describes preventative and response measures that will be implemented in the event of a spill (*see* Appendix D). As noted above, a Project-specific SPCC also will be prepared.

Where technically feasible, Broadwater proposes to use a subsea plow as the primary means of lowering the pipeline below the seabed, which will decrease the amount of sediment introduced into the water column when compared to other installation technologies that could be utilized. As previously discussed by FERC in recent projects proposed or constructed in the Long Island Sound (see FEISs for the Eastchester Project [Docket No. CP00-232-000] and the Islander East Pipeline Project [Docket No. CP01-384-000]), both jetting and dredging installation technologies are recognized to cause greater disturbance to sediments and disperse sediments over a much larger volume of the water column than the subsea plow, which has been the recommended construction methodology, where feasible.

Alternate construction technologies will be used at the IGTS tie-in location, FSRU tie-in, AT&T cable crossing, CSC crossing (manual excavation by divers and/or the use of submergeable pumps) where the presence of existing utilities precludes the use of conventional construction, and dredging may potentially be used in the Stratford Shoal Middle Ground area if plowing is deemed infeasible. An installation summary, including affected acreages and volumes, is included in Table 2-8 below. Additional details regarding pipeline installation methodologies are provided in Resource Report 1, General Project Description.

Table 2-8 Broadwater Pipeline Installation, Summary of Sediment-Related Impacts Along the Pipeline Corridor

Impact Type	Sediment Volume (cu yards)	Impact (acres)	Comment
Pipeline lowering via plow; 19.7 miles with 3 feet of cover	304,500	179.1	Impacts include both the trench excavation and associated spoil mounds.
Pipeline lowering via plow; 2 miles with 5 feet of cover	39,500	18.2	In proximity to the FSRU, the pipeline will be lowered to a greater depth to accommodate design considerations.
AT&T cable crossing	3,030	0.4	Impacts include excavations for a cable crossing bridge and pipeline trench transition.
Cross Sound Cable crossing	3,030	0.4	Impacts include excavations for a cable crossing bridge and pipeline trench transition.
FSRU tie-in	1,650	0.2	Includes pipeline expansion loop.
Check and isolation valve spool	270	< 0.1	Located approximately 2,000 feet from the YMS tower

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Table 2-8 Broadwater Pipeline Installation, Summary of Sediment-Related Impacts Along the Pipeline Corridor

Impact Type	Sediment Volume (cu yards)	Impact (acres)	Comment
IGTS tie-in	2,340	0.3	Includes expansion offset
Anchor footprint	N/A	16	8-point mooring, three anchor sets per mile, and three passes (one lay, and two plow)
Anchor cable sweep	N/A	2,020	8-point mooring, mid-line buoys on quarter anchors, three anchor sets per mile and three passes (one lay, and two plow)
Total	354,320	2,234.7	

Sediment Resuspension/Redeposition

Construction of the marine pipeline will unavoidably result in some resuspension of bottom sediments in conjunction with excavation of the pipeline trench. The suspended sediments will have a localized, short-term and minor impact on water quality during installation activities. The detailed sediment modeling analysis is presented in Appendix E. The Addendum to Appendix E provides greater detail where the modeling results indicated TSS levels greater than $14 \,\mu\text{g/L}$. The lack of significant contamination within the Project area, based on the detailed field sampling effort, limits impacts primarily to localized, short-term increases in TSS in the water column.

The proposed primary means of installing the pipeline will involve the use of a subsea plow. Unlike jetting, which requires the liquefaction of the sediment for removal, the subsea plow simply pushes the ditch spoil material to either side to form the trench, minimizing the amount of sedimentation. Resuspension of sediments would be limited to the fine-grained sediments present at the water/sediment interface that would have a higher water content and be comprised of silt or clay material. Coarser sediments such as sands and gravels would experience relatively little or no dispersion into the water column in conjunction with plowing activities. Subsea plowing is generally accepted as the agency-preferred means for installing marine pipelines in Long Island Sound. At tieins and utility crossings, the pipeline trench will be excavated either by divers or by use of a submersible pump. Because these areas are very limited in size, the amounts of sediment resuspended during these isolated excavations are expected to be minimal.

To assess the magnitude, duration, and extent of turbidity and sedimentation associated with the proposed pipeline construction, impacts were modeled using the MIKE3 sediment model. Prior to initiating modeling efforts for this Project, regulatory agencies, including the EPA, USACE, NYSDEC, and the New York State Department of State (NYSDOS), were given the opportunity to review and comment on the proposed modeling protocols (*see* Appendix B).

The volume of sediments anticipated to be resuspended in the water column as a result of installation of the pipeline was input into the model for analysis. The volume of sediment

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anticipated to be displaced is based on the trenching technology used, the dimensions of the trench, and the porosity of the sediment. The pipeline trench will be excavated over two successive passes of the subsea plow, with a maximum of 5 feet of sediment removed in the first plow pass. As a conservative estimate, approximately 20% of sediment material would be introduced into the water column. This estimate was used based on past modeling practice and professional experience, which indicates that the average percentage of sediment material introduced into the water column is 2% to 5%. Using the value of 20% eliminated the need to perform a sensitivity analysis for this variable, since assuming such a high percentage generates a worst-case scenario for model output. Based on the anticipated levels of material that will be introduced into the water column, the impacts, which are not significant as modeled, will actually be considerably less than modeled. Unlike jetting (which will result in high-energy dispersion) or dredging (which can result in the introduction of sediment throughout the water column), plowing will result in extremely low-energy introduction of sediment into only the bottom-most portion of the water column. Inputs to the MIKE3 model were provided based on pipeline design and completion of sediment sampling program in April-May 2005, which included chemical, physical and geotechnical analysis of the sediments along the proposed pipeline route.

In addition to sediment resuspension, the introduction/reintroduction of contaminated sediments into the water column could result in additional impacts from construction. The Broadwater sediment sampling program was developed to evaluate the site-specific sediment conditions along the proposed pipeline route and was designed specifically to address NYSDEC, Division of Water's TOGS 5.1.9 for In-Water and Riparian Management of Sediment and Dredged Material (November 2004). The sediment sampling plan included analysis for several different contaminants at a minimum interval of one sediment sample per mile along the proposed pipeline route, with adjustments to shorten or lengthen the interval applied to account for historical contamination data, field literature and field-identified changes in sediment type, which may be indicative of changes in the level of potential contamination (*see* Figure 2-6). Sediment sampling was performed through a coring operation in which a 10-foot (3 m) sediment core was collected from each sample location using a vibracore unit mounted on a 100-foot (30 m) survey vessel. Once retrieved, the sediment core soil types were classified, and sediment samples were collected from the core and shipped to a laboratory for chemical analysis.

The laboratory results indicated that the metals concentrations detected did not exceed any of the NYSDEC TOGS criteria, and analytes for all other contaminant groups evaluated, including PAHs, PCBs, pesticides, VOCs, and dioxin, were not detected in any of the samples (see the Spring 2005 Environmental Sampling Report). Based on the lack of elevated contamination levels in the analytical results, only the physical impact of the sediment disturbance from the pipeline was evaluated in the sediment model since it was verified that no chemical contaminants of concern were present along the proposed pipeline route.

As previously mentioned, the MIKE3 model was used to determine the physical extent to which sediments will be dispersed and the depth of deposition. The mass of sediment

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released was calculated based on the volume displaced and the density and porosity data collected (see Appendix F – Grain Size Data). As a 3-dimensional model, impacts at the surface, in the middle of the water column, and at the bottom could be assessed. Some sediment will become suspended in the water column and dispersed as a result of installation activities. The proposed use of a subsea plow as the primary installation techniques largely restricts impacts to temporary increases of TSS in the bottom strata where the sediment is introduced. Complete modeling results are presented in Appendix E. While the modeling shows some dispersion of sediment to the middle strata and eventually the surface strata, concentrations of TSS are quite low in these strata (less than 10 mg/L and mostly less than 5 mg/L, which are within background levels for the sound [NYCDEP 2005]) and would largely not be visible. Figures 2-11a through 2-11i present representative TSS concentrations within the Project area showing the transient nature of the TSS spikes that occur as a result of plowing operations. Figures 2-11g and 2-11h are also provided with an expanded scale to identify the complete range of TSS values on the bottom that are greater than 14 mg/L. The primary tidal currents, which largely parallel the longitudinal axis of the Sound, result in TSS concentrations that largely dissipate along the central axis of the Sound, rather than drift toward more sensitive inshore habitats. Based on the results of the modeling, limited minor, short-term changes in TSS levels in the vicinity of the active construction area will occur.

The minimal levels of TSS modeled in the Project area will largely restrict sedimentation outside the pipeline corridor. The slow speed of the subsea plow, coupled with the subsea plow mechanics of simply pushing sediment out of the trench into adjacent spoil piles, limits the dispersion of sediment to primarily the silt and clay components. Material with a more sandy/gravelly composition will simply be deposited in the adjacent spoil piles. Figures 2-11a through 2-11i provide graphic representations of TSS levels generated on the surface, at mid-depth, and at the bottom. As evident in the figures, significant spikes are restricted to a localized area on the bottom in immediate proximity to the trench, and any increases in TSS levels are largely assimilated on the surface. Figures 2-11c, 2-11f, and 2-11i demonstrate that within 12 hours following completion of the plowing, the TSS levels are largely assimilated throughout the Sound. The results show that sediment levels are largely dispersed within one to two complete tidal cycles in the Sound.

Figures 2-12a through 2-12g provide TSS levels at a fixed location along the route corresponding with plowing operations. The plow was modeled to pass this location (approximately MP 10.2) at approximately timestep = 150 and corresponds to Figures 2-11a, 2-11d, and 2-11g.

The figures indicate that TSS levels are largely entrained within the water column, with TSS levels decreasing with distance from the pipeline corridor through minimal settling and dilution. Studies in Long Island Sound have demonstrated that most infaunal

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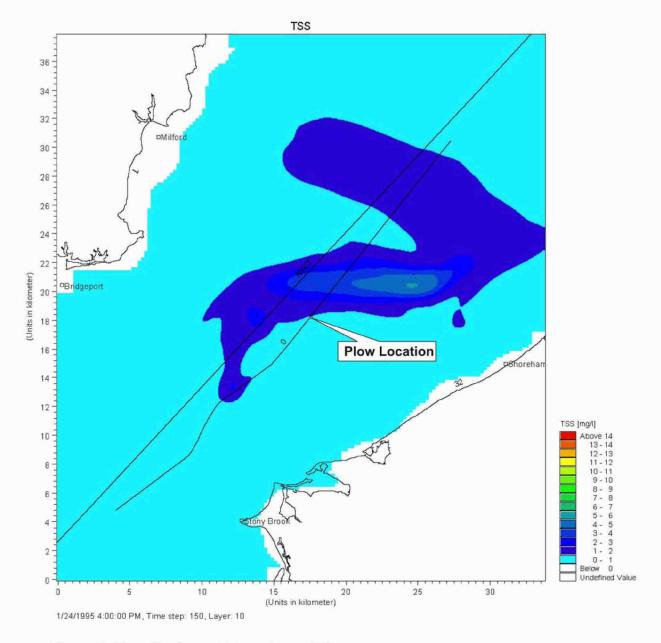


Figure 2-11a Surface at Timestep = 150

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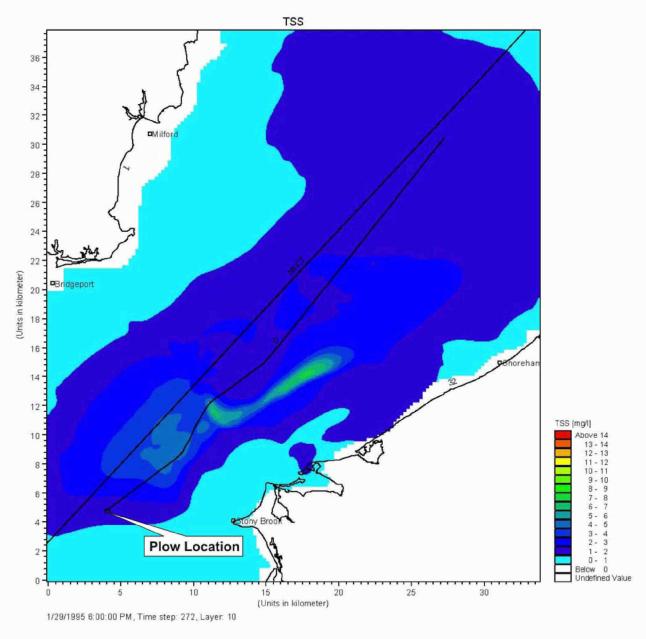


Figure 2-11b Surface at Timestep = 272 (end of plowing)

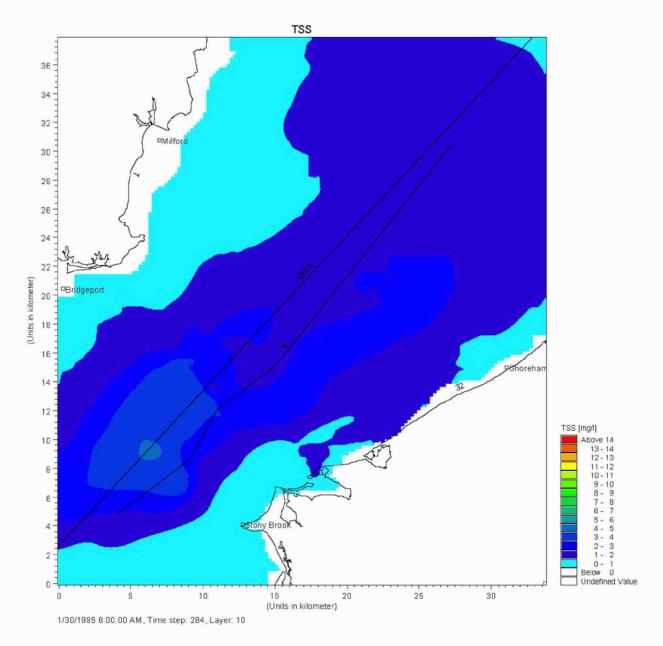


Figure 2-11c Surface at Timestep = 284 (12 hours after end of plowing)

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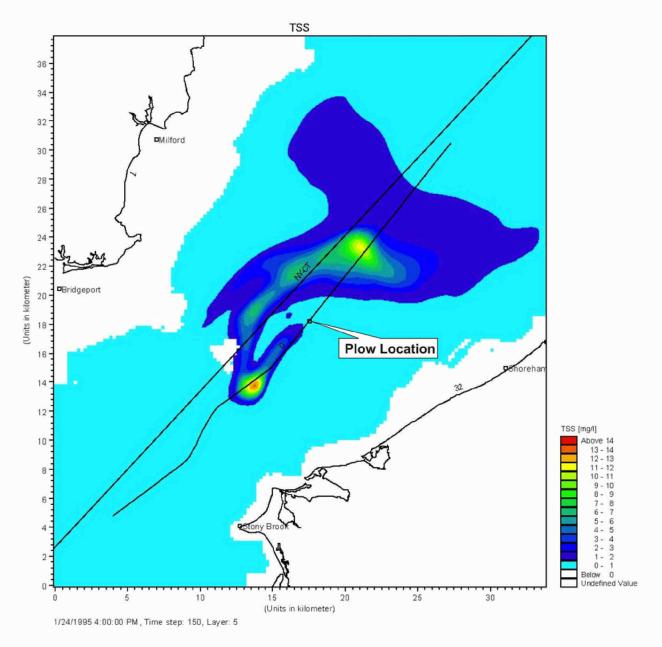


Figure 2-11d Mid-depth at Timestep = 150

2-52 PUBLIC

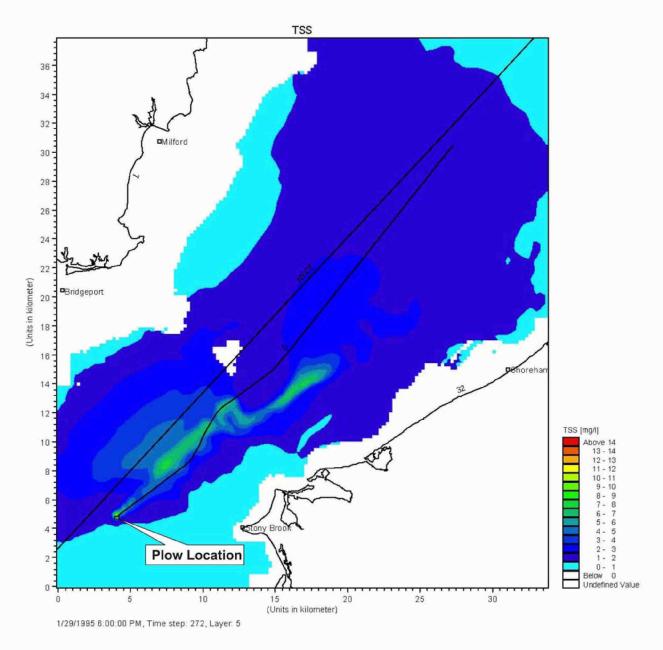


Figure 2-11e Mid-depth at Timestep = 272 (end of plowing)

2-53 PUBLIC

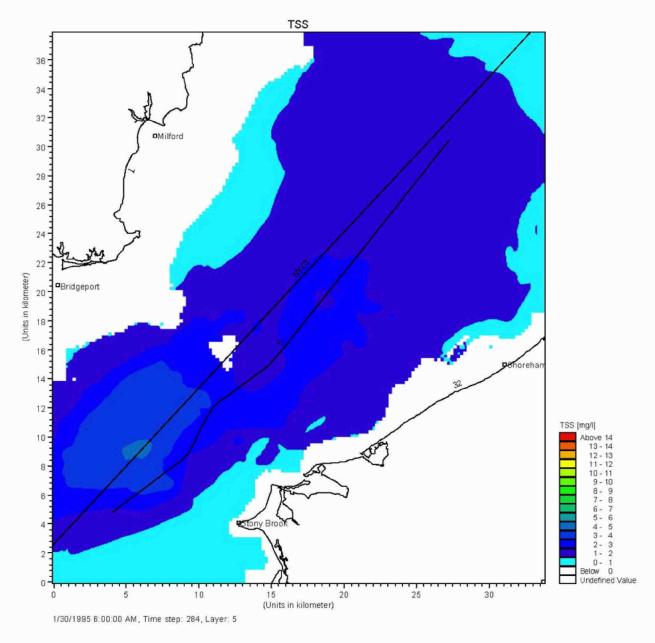


Figure 2-11f Mid-depth at Timestep = 284 (12 hours after end of plowing)

2-54 PUBLIC

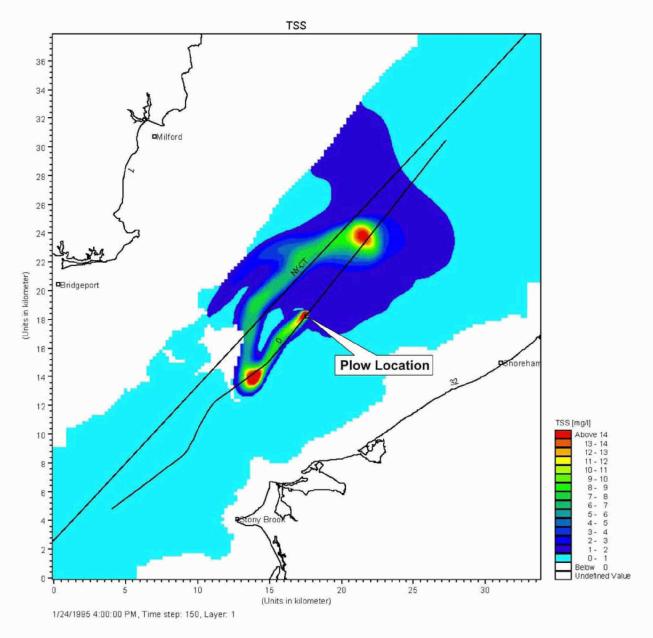


Figure 2-11g-a Bottom at Timestep = 150

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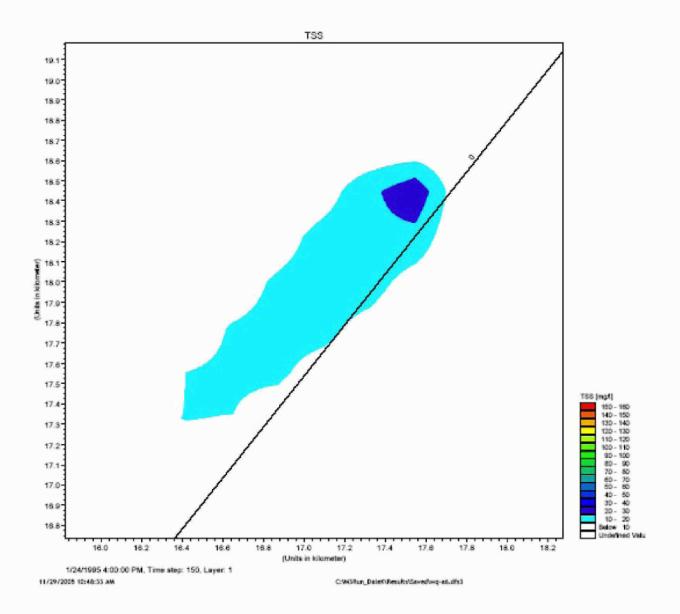


Figure 2-11g-b Expanded Bottom TSS Scale at Timestep = 150

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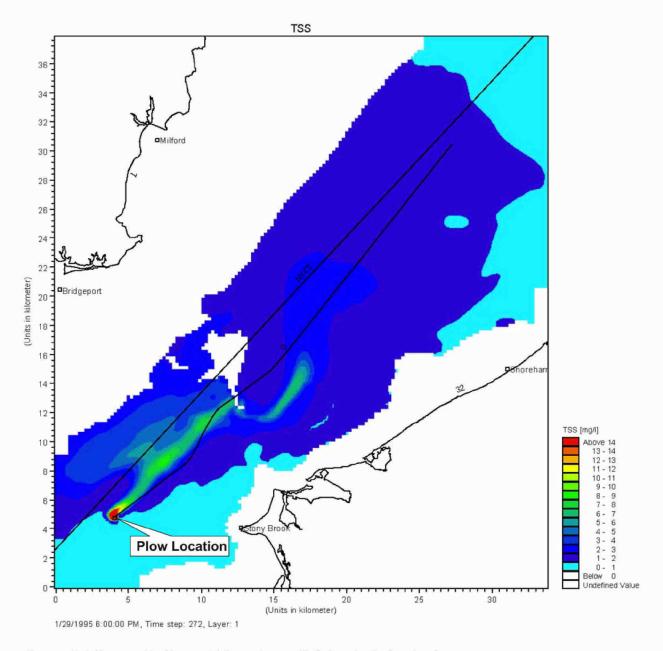


Figure 2-11h-a Bottom at Timestep = 272 (end of plowing)

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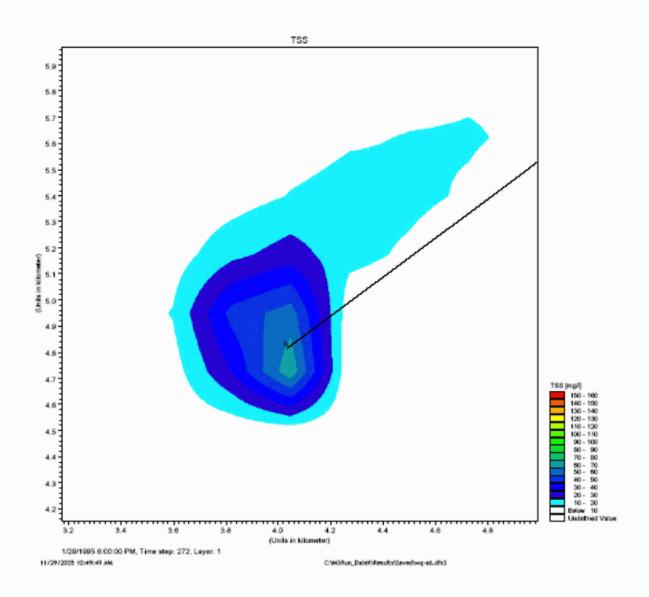


Figure 2-11h-b Expanded Bottom TSS Scale at Timestep = 272

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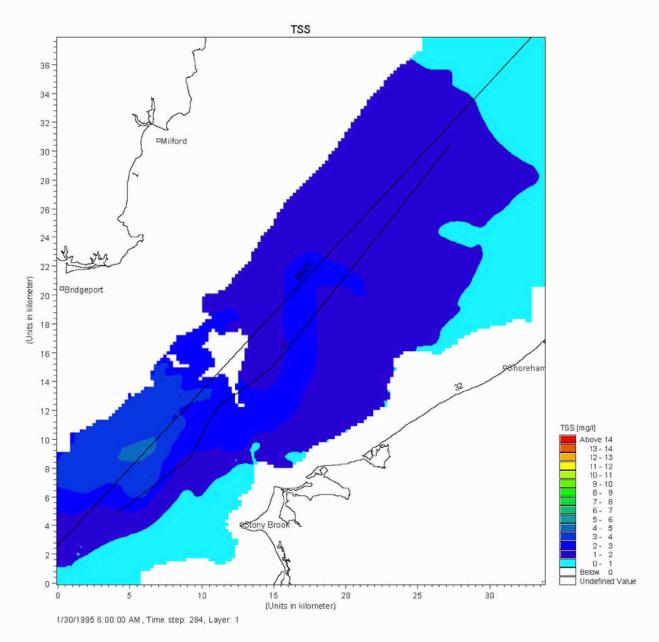


Figure 2-11i Bottom at Timestep = 284 (12 hours after end of plowing)

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On top of Route

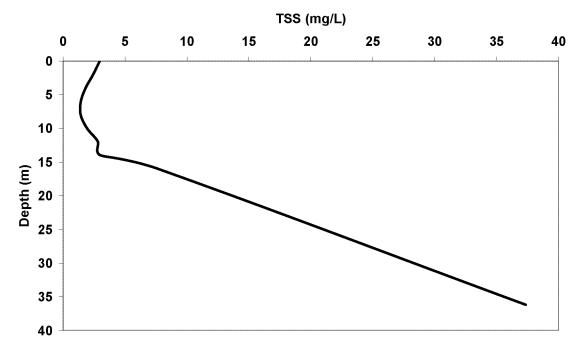


Figure 2-12a Top of Route

250ft from Route - South

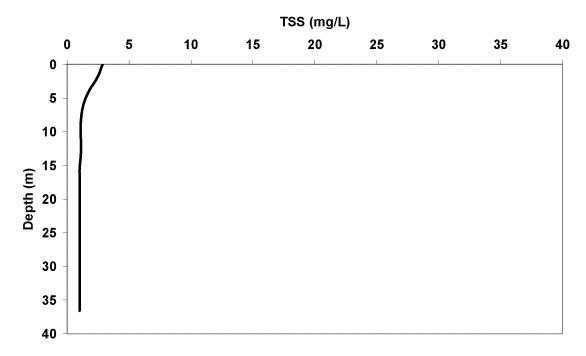


Figure 2-12b 250 Feet from Route - South

500ft from Route - South

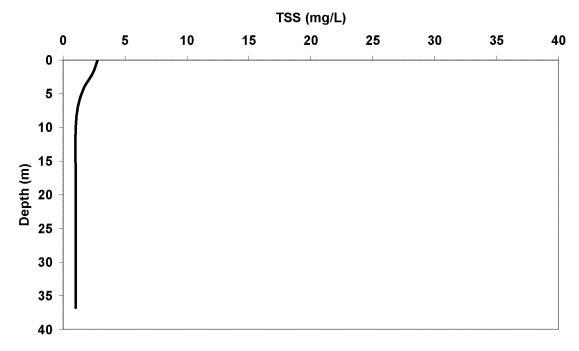


Figure 2-12c 500 Feet from Route - South

750ft from Route - South

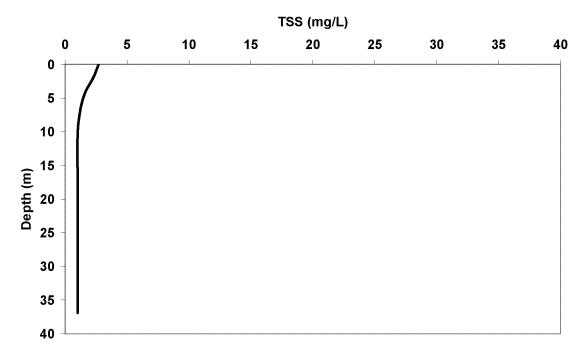


Figure 2-12d 750 Feet from Route - South

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250ft from Route - North

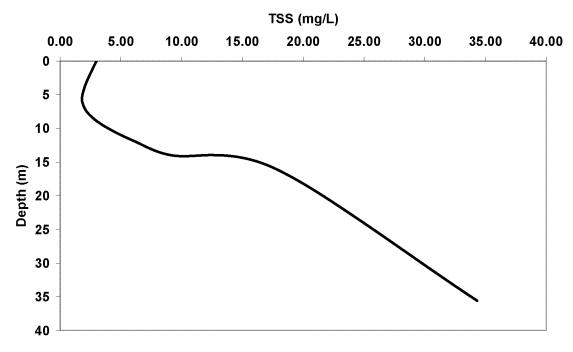


Figure 2-12e 250 Feet from Route - North

500ft from Route - North

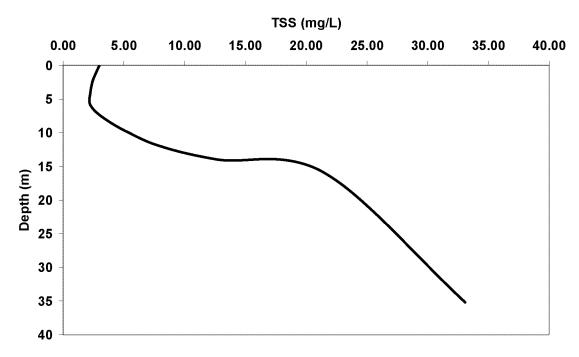


Figure 2-12f 500 Feet from Route - North

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750ft from Route - North

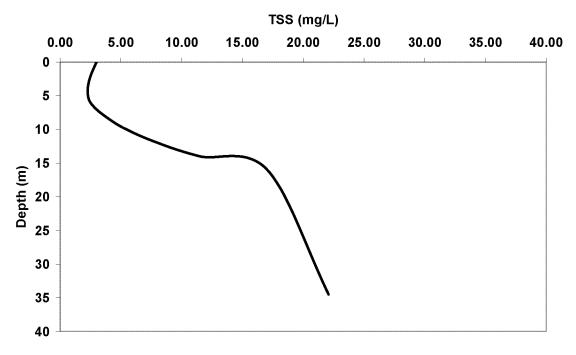


Figure 2-12g 750 Feet from Route – North

organisms can survive burial to a depth of 4 inches or less (Kranz 1974; Nichols et al. 1978). Based on the modeling results and the lack of significant TSS concentrations within the water column, no significant sediment settling that could adversely affect existing biota is anticipated beyond the central construction corridor.

Separate modeling was also conducted to address potential sedimentation impacts from the excavation activities associated with the IGTS and FSRU tie-ins, as well as the crossing of foreign utilities, which prevent the use of the subsea plow. The sediment modeling for these activities shows almost no discernable increase of TSS in any of the water strata, largely due to the minimal amount of sediment that will be excavated at each location and the assimilative capacity of the Long Island Sound.

In addition to assessing the suspended sediments anticipated within the water column from construction, separate modeling was conducted to determine the sediment deposition that would occur in conjunction with proposed pipeline installation activities associated with the plowed trench. Based on a total spoil and open trench area width of 75 feet (23 m) (includes two 25-foot-wide spoil piles and a 25-foot-wide pipeline trench), the modeling for the proposed subsea plow shows that the maximum deposition depth anywhere along the route outside the 75-foot (23 m) corridor is just under 0.19 inch (5 mm). Depths greater than 0.04 inch (1 mm) are restricted to a distance of approximately 300 to 660 feet (100 to 200 m) from the pipeline route. Given the limited spatial extent and depths, is it unlikely that there will be any impact from sediment deposition due to pipeline installation (see Appendix G).

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The proposed excavation of Long Island sediment will result in the turnover of bottom sediments (i.e., exposure of particles and pore water solutes from buried anaerobic sediments to the aerobic or hypoxic sediment surface). This redistribution of sediment (and change in redox conditions) can result in the release of pore-water solutes (reduced metal sulfides and reduced metabolites [e.g., hydrogen sulfide, ammonia, nitrate, nitrite, phosphate, and methane gas]). The proposed excavation will not change the overall inventory of contaminants, but changes in redox conditions would be expected to change solubilities, flux rates, and rates of aerobic decomposition through enhanced chemical and biological oxidation. The lack of significant contaminant accumulation in the Project sediments (see Section 2.3.6) largely eliminates concerns regarding the redistribution of contaminants in the Project area. Localized exposure of reduced sediments to the water column (i.e., in a sediment plume) and on the bottom is expected to result in enhanced chemical and biological oxygen demand. Once the sediment surface has been reoxidized, oxidation rates are expected to converge with the adjacent ambient bottom conditions. While hypoxia has been identified as a potential issue in Long Island Sound, hypoxic conditions are largely restricted to the warmer summer months and are concentrated in the westernmost portion of the Sound, which is subject to greater anthropogenic discharges. The proposed marine pipeline will be installed in the winter months, when hypoxic conditions are largely absent from the Sound. Only highly localized short-term impacts are anticipated from construction of the marine pipeline.

Hydrostatic Test Water Discharge

In addition to sediment disturbance during pipeline installation, the discharge of hydrostatic test water may potentially affect water quality along the proposed pipeline route. Hydrostatic testing ensures the operational integrity of the pipeline and all connecting assemblies and will be performed following installation and prior to complete tie-in with the FSRU and IGTS system for full pipeline operation. Best industry practices will be used to minimize potential impacts on surrounding water quality. Hydrostatic testing involves flooding of the pipeline with seawater infused with a biocide material to prevent microbiologically influenced corrosion on the pipeline interior. The total volume of seawater required to fill the proposed 21.7-mile-long (35-km), 30-inch-diameter pipeline is approximately 3,909,520 gallons (14,799 m³). This represents less than 0.00000028% of the water present in the entire Sound and, therefore, is not expected to have an impact on water quality.

During the testing process, clean seawater will be filtered through a 200 size mesh screen (mesh opening = 0.0029 inches [0.07 millimeters]). The filtering prevents debris and foreign material from entering the pipeline. The suction head or submersible pump will take in water at a depth of approximately 20 to 40 feet below the water surface to minimize the introduction of more highly oxygenated water and microorganisms into the pipeline. The fill rate for the hydrostatic test water into the pipeline will be approximately 4,000 gallons/minute.

To protect the pipeline from excessive corrosion, a biocide will be added to the hydrostatic test water. As long as there is water in the pipeline, there are many types of

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microorganisms that can begin the process of corrosion, impacting the integrity of the pipeline. Since test water will likely remain within the pipeline for greater than 14 days, a biocide must be added to reduce corrosion in the pipe. The pipeline will remain flooded between the installation and testing of the pipeline in spring of 2010 until final tie-in and dewatering at the end of 2010, thus requiring the need for a biocide.

The toxicity of biocides will be neutralized to avoid adverse effects on the environment after discharge. Prior to pipeline commissioning, the hydrostatic test water will be pumped to holding tanks on a support vessel on the surface for treatment/neutralization with a neutralizing chemical (e.g., hydrogen peroxide). After allowing time for adequate neutralization, the hydrostatic test water will be re-oxygenated (e.g., through use of a diffuser) and discharged into the Sound. The rate of discharge back into the sound is estimated to be 2,000 gallons/minute (7.6 m³/minute). No swabbing chemicals/drying agents will be used during the dewatering process. Only clean, filtered, oil-free air will be used for the displacement of dewatering pigs.

The hydrostatic test water will not be directly discharged from the pipeline into the marine environment; it will be neutralized prior to discharge. Therefore, the hydrostatic testing and dewatering process will have no impact on the water quality of the Sound and only represents a water exchange that will be removed and returned over a seven-month period.

2.5.1.2 FSRU and Stationary Tower Structure

No impacts on water quality are expected to result from installation of the FSRU. The FSRU will be ballasted at the construction yard before commencing the tow to Long Island Sound. In compliance with the International Convention for the Control and Management of Ships Ballast Water and Sediments, a ballast water exchange will be completed during the voyage. Regulations require this to be conducted at least 200 nautical miles from the nearest land and in water at least 200 meters in depth, with an efficiency of 95% volumetric exchange of ballast water.

The International Convention has been set forth in 33 CFR Subpart D – Ballast Water Management for Control of Nonindigenous Species in Waters of the United States.

Based on the exchange of ballast water before the FSRU enters Long Island Sound, and its use as a static object located only in Long Island Sound and not in transit, a Ballast Water Management Plan will not be prepared or implemented.

Since the FSRU will be a stationary facility in a marine environment, antifouling paint will be used to minimize growth on the FSRU and stationary tower structure. Recognizing the concern over potential impacts from antifouling paint, Broadwater will use a copper-based antifouling paint rather than a tri-butyl tin-based paint, which would result in greater ecological impact. Even with the use of a copper-based paint, some leaching and associated impact will occur. The potential impacts of copper leaching were assessed and compared to ambient water quality standards. Based on the analysis, the

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copper leaching from the FSRU will not result in adverse impacts. The antifouling paint will be applied at the shipyard during construction of the FSRU. The most significant leaching of copper is expected to occur in the shipyard and during the towing of the FSRU to the mooring tower location. By the time the facilities are installed in Long Island Sound, it is anticipated that the copper leaching from the antifouling paint will have reached a maximum steady state of $39.99 \,\mu\text{g/cm}^2/\text{day}$ (International Paint Ltd. 1998). Based on the volume of paint required to cover the necessary surface area of the facility, the estimated rate of copper leaching is estimated to be 12.6 kg per day.

Based on this leaching rate for copper into the aquatic environment, a theoretical cylinder of potentially impacted water was calculated to determine the approximate copper concentration that may be present in the water column. The derived cylinder constitutes a given volume of water based on the radius of the FSRU as it weathervanes around the mooring tower and a water depth of approximately 100 feet (30 m) at the FSRU location. These assumptions equal a cylindrical volume of water in the immediate vicinity of the FSRU of 12,536,770,000 liters. This volume was calculated as follows:

 $V = \cdot \cdot \mathbf{r}^2 \mathbf{H}$ where V equals cylinder volume, r equals the weathervane radius around the mooring tower, and H equals the depth of the water column.

```
= (3.14)(363^2)(30.3 \text{ m})
= (12,536,766.19 \text{ m}^3, \text{ or } 12,536,770,000 \text{ liters of water}).
```

An additional calculation also was performed to convert the 12.6 kg per day of copper that may leach into the water column to μg , resulting in 12,600,000,000 μg .

Once these conversions were complete, the overall equation was reduced as follows:

```
\frac{12,600,000,000 \, \mu g}{12.536,770,000 \, liter} = 1.005 µg of copper/liter of water
```

This calculation was performed to arrive at a concentration reported in $\mu g/L$, since the EPA ambient water quality criteria for copper is reported in these units (EPA 2003). The EPA water quality criterion is the threshold value for comparison to the copper concentration generated by the FSRU to determine whether copper present in the antifouling paint used on the hull will impact aquatic organisms in the vicinity of the FSRU.

The water quality criteria promulgated by the EPA for the protection of aquatic organisms indicates that, with the exception of locally sensitive species, the saltwater aquatic organisms and their uses should not be impacted if the 4-day average concentration of dissolved copper does not exceed 1.9 $\mu g/L$ more than once every 3 years and if the 24-hour average concentration for dissolved copper does not exceed 3.1 $\mu g/L$ more than once every 3 years. By comparing the calculated value of 1.005 μg copper/liter of water with these criteria, it can be concluded that there will be no impact on water quality or aquatic organisms due to the leaching of copper from the antifouling paint present on the FSRU hull.

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Minimal sediment disturbance will take place during installation of the tower, which will be used to moor the FSRU and secure the send-out pipes. This operation is expected to affect a limited bottom sediment area of approximately 25,000 square feet (2,322 m²) (accounting for anchor disturbance and the actual footprint of the mooring tower), and the duration of piling and platform operations for supporting the mooring tower structure will last approximately six weeks. These activities will have only a short-term, minor impact on water quality based on the small volume of sediments that will be disturbed and the short duration of installation activities.

2.5.2 Operation

2.5.2.1 **Pipeline**

Impacts on water quality from operation of the pipeline will be minimal since the pipeline is a closed system that will have limited contact with the surrounding waters. The areas that will have direct contact with the surrounding waters include the pipeline section from the FSRU to the foot of the riser on the seafloor that connects through the tower and the open pipeline trench, which will be open for approximately 200 days following construction. The value of 200 days is based on the natural backfill modeling analysis that was performed for the pipeline (*see* Appendix H).

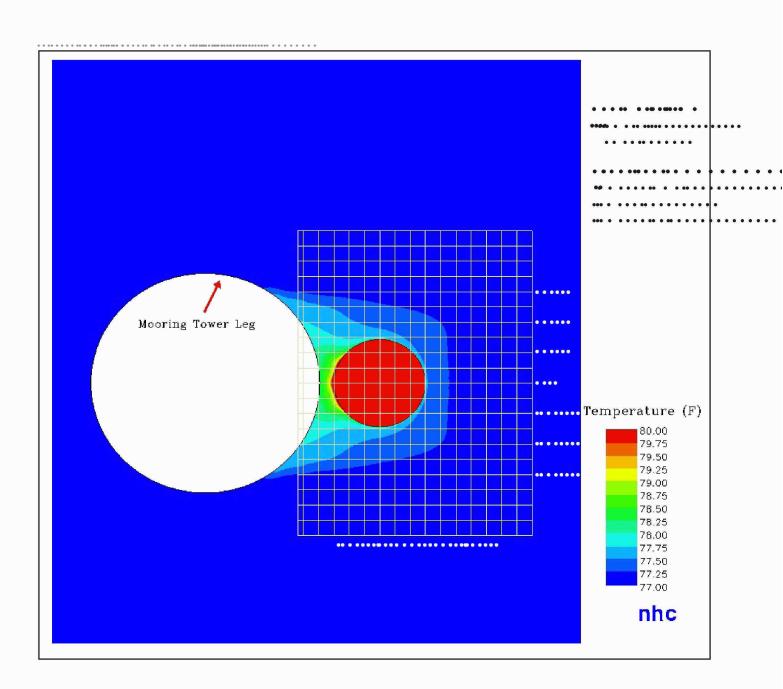
Pipeline Riser

The potential exists in the exposed pipeline areas for a thermal exchange between the pipeline and the surrounding waters, since the natural gas in the pipeline during low flow periods (i.e., less than 1 bcfd) is at a temperature of 130 °F (54 • C) as it exits the FSRU, dropping to approximately 120 °F (49 •C) once it reaches the foot of the riser on the seafloor. This represents a 140-foot section of pipeline that will remain in direct contact with the surrounding water and will lose 10 °F (5.5 • C) as it descends to the seafloor. (At higher gas flows, i.e., 1 bcfd and higher, the temperature of the send-out gas would be reduced to approximately 100 •F [38•C] through the riser.) With the 10 °F loss of heat over the 140-foot section of pipeline, heat transfer to the surrounding water column will occur. This heat transfer was modeled, and impacts from the riser are demonstrated only for the water immediately surrounding the pipeline to a distance of approximately 1 pipe diameter (30 inches). The heat transfer does not create a thermal plume, since mixing of surrounding water and current flow past the pipeline quickly dissipate any heat and return the water to ambient temperatures at distances greater than 1 pipe diameter. The modeling results are summarized on Figure 2-13, and the complete thermal modeling report is provided as Appendix I.

Installed Pipeline - Open Trench

In addition to the pipeline riser, which will be permanently exposed in the water column, the installed pipeline also will be temporarily exposed to the water column until sufficient natural backfilling occurs, and there is potential for short-term thermal impacts during the time the pipeline trench is open. As noted above, the trench will be open for approximately 200 days. Unlike the riser, the installed pipeline will be partially insulated

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by a concrete coating which, coupled with the decreasing gas temperatures downstream from the FSRU, will result in minimal impacts. The potential for heat transfer from the pipeline in the open trench will impact only the water immediately surrounding the pipeline at a distance of approximately 1 pipe diameter (30 inches) and may create a plume of warmer water over the open trench (see Figure 2-14). To assess the worst-case scenario, the modeling assumed a current parallel to the pipeline, whereas the current will actually cross the pipeline at some angle, minimizing the potential cumulative impact modeled under the worst-case scenario. The mixing of water will occur constantly as bottom currents pass over the open trench, and this mixing will minimize any thermal impacts. In addition, these impacts will be short-term since the connection between the open water and the pipeline will be reduced as the trench continues to fill in with depositional material, and after 200 days the pipeline will be completely covered with depositional material. Details of the open trench thermal modeling setup and the complete results are presented in Appendix I.

Installed Pipeline - Covered Trench

The third scenario modeled to assess thermal impacts was the covered trench. This represents the long-term condition of the pipeline during operation. As indicated by the modeling results presented in Appendix I, there is no thermal impact on the water column from the pipeline once the pipeline trench is backfilled (see Figure 2-15). Once backfilling has occurred, any thermal influence the pipeline had on the surrounding water is eliminated.

Following commissioning of the Project, periodic maintenance will be required to assess the integrity of the pipeline during its life cycle. Since the pipeline will largely be installed below the seafloor, with backfilling occurring either naturally or with engineering backfill, any significant maintenance activities will require isolated excavation and day-lighting of the pipeline. Impacts are anticipated to be of a lesser scale than the impacts associated with the original installation of the IGTS and FSRU tie-ins. Submersible pumps and/or diver-assisted excavations will be required to expose the pipeline and valve assemblies, and attach the pig launcher and receiver facilities at either end of the pipeline. Following successful testing, the pipeline valve assemblies will be re-backfilled to provide protection of the pipeline and valve assemblies. Short term, minor, and localized sedimentation impacts will occur in conjunction with the maintenance activities. It is anticipated that maintenance/pigging operations will be conducted approximately every 5 to 7 years.

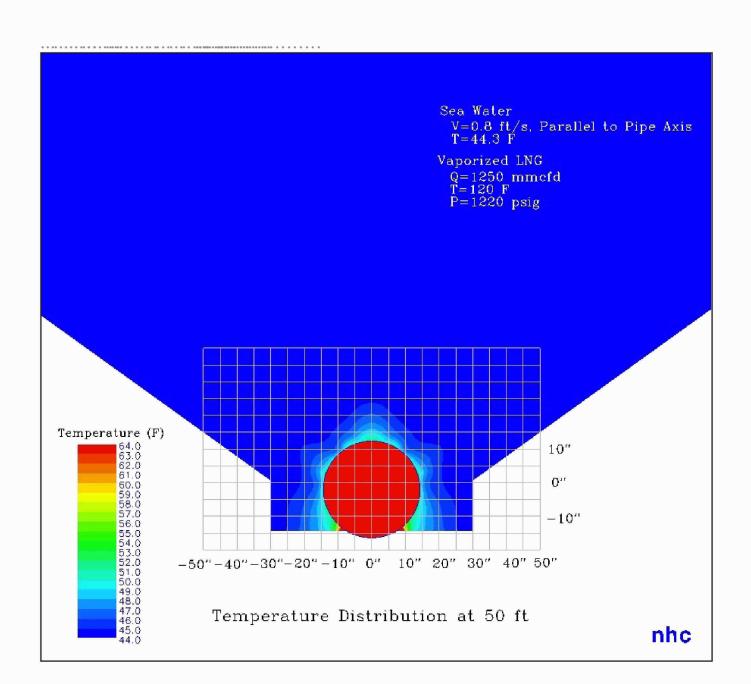
2.5.2.2 FSRU Operational Requirements

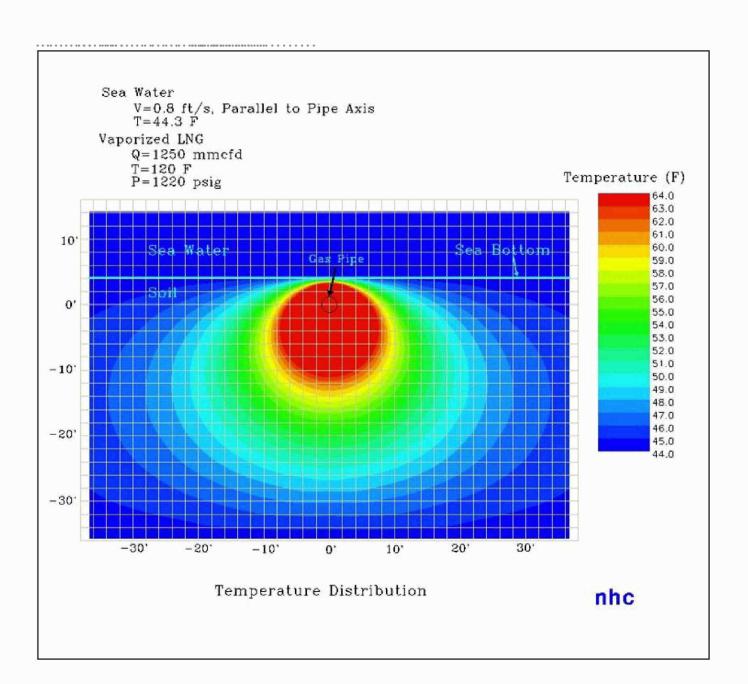
Routine operation of the FSRU involves water intakes and discharges that have the potential to impact water quality. The intakes and discharge points remove and return water from the Sound at various rates based on FSRU operations.

FSRU Sea Chest Intakes

The intakes associated with continuous FSRU operations are comprised of two sea chests located port and starboard at the bottom of the FSRU hull. Water from these intakes is used primarily for all treated seawater systems, including:

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- Ballast for the FSRU to maintain FSRU trim, stability, and draft depth during LNG transfer from the carrier to the FSRU, and during send-out operations;
- To make potable water (via a desalination unit);
- For the marine growth prevention system (MGPS); and
- Side-shell water curtain (to maintain hull integrity during LNG transfer from the carrier to the FSRU).

In addition to the daily uses, on an infrequent basis water from the sea chests will support the bilge and general services pump, the seawater cooling pump, and the inert gas (IG) scrubber cooling pump.

The sea chest seawater intake system consists of a cross-over pipe between port and starboard that allows all seawater-based operating systems on the FSRU to be supported from either intake. Only one intake will operate at any given time. Each sea chest would have an approximately 35-inch (88.9-cm) cross-over pipe leading to a 0.2-inch (5-mm) mesh screened intake. A coarse grate, flush with the FSRU hull, will exclude marine life larger than the grate size, which will be approximately 4 inches by 2 inches (10 by 5 cm). Sodium hypochlorite will be injected at a point in the sea chest between the course grate and small mesh screen at a continuous dose of 0.2 parts per million (ppm). The concentration of the sodium hypochlorite in the sea chest will quickly dilute to a concentration between 0.01 and 0.05 ppm. A positive pressure flow on the intake system of approximately 0.5 ft³/second (0.15 m/s) will ensure that water treated with sodium hypochlorite does not re-enter the water column from the sea chest. Based on a gas send out of 1 bcfd, the sea chest intakes will supply approximately 6.6 million gallons (24,840 m³) of treated seawater per day for all FSRU operations. The FSRU does have the potential to operate at a peak gas send out of 1.25 bcfd for a short time, although the annual average will not exceed 1.0 bcfd. At this peak gas send out, the sea chest intakes will supply approximately 8.2 million gallons (31,050 m³) of treated seawater per day for all FSRU operations.

Fire-Water Intake

The fire-water intake system consists of two intakes located fore and aft on the FSRU. These intakes are not treated with sodium hypochlorite. The fire-water intake structure will be similar to the sea chest intakes, but without the 5-mm screen. A coarse grate, flush with the FSRU hull, will exclude marine life larger than the grate size, which will be approximately 4 inches by 2 inches (10 by 5 cm). The maximum rate for seawater intake at the fire-water suction is 0.74 million gallons/hour (2,800 m³/hr) based on peak fire-water pump operation. These pumps will operate at this level if there is a fire emergency onboard the FSRU. Otherwise, this system will be operationally tested for one hour every 30 days, with a total seawater intake of 0.74 million gallons (2,800m³) per test.

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Intake Volume

The total daily water intake by the sea chests to support all FSRU operations will be approximately 6.6 million gallons (24,840 m³). This assumes an intake volume 21,600 m³ of ballast water over a 24-hour period, which equates to 5.7 MGD and a 15% contingency for all other systems that require seawater, which equates to 0.9 MGD.

The sea chest seawater suctions will operate continuously to supply treated water to various systems on the FSRU, while the fire pump suctions will be utilized only one out of every 30 days for monthly fire-water testing. Typical total water intake volumes for the FSRU during normal operations are approximately 6.6 MGD, which will increase to approximately 7.3 MGD once a month during fire-water testing. All FSRU operations contributing to water intake volumes are described in detail below.

2.5.2.3 FSRU and Carrier Operations

2.5.2.3.1 FSRU Ballast System

To maintain draft, trim, and stability and limit hull stresses, the FSRU will load and discharge seawater ballast in the same way as other commercial vessels. The ballast tanks are located in the double-hull space surrounding the cargo tanks and are connected to the ballast pumps via a ring main piping system. The pumps are situated in the machinery space, with seawater suctions located at the bottom of the FSRU, flush with the hull. The ballast discharge point is located at the side of the machinery space, slightly below the waterline on both port and starboard sides of the FSRU. A detailed description of the ballast system is presented in Resource Report 13.

The density of LNG relative to seawater is approximately 0.45, and ballast water is either taken on or discharged based on this density ratio. During normal gas send-out operations when an LNG carrier is not offloading, the FSRU will take in ballast water at a rate of approximately 900 m³/hr (approximately 238,000 gallons/hr) to compensate for the reduction in LNG inventory of 2,000 m³/hr. When an LNG carrier is offloading, the FSRU will deballast at approximately 3,600 m³/hr (0.9 million gallons/hr) to compensate for the weight of LNG being loaded, less the normal gas send-out quantity.

To control the growth of marine organisms, the FSRU seawater intakes will include the ability to inject a continuous dose of sodium hypochlorite at a concentration of 0.2 ppm. That dose will result in a residual chlorine concentration between 0.01 to 0.05 ppm at the sea chest and at the ballast water discharge. This residual chlorine concentration is not expected to have an affect on water quality since dilution at the discharge point will occur quickly due to the influence of tides and general water circulation within Long Island Sound.

Sodium hypochlorite will be produced from the intake sea water by an electrochlorination unit that, by passing an electric current through a seawater cell via two concentric titanium electrode tubes, converts the sodium chloride in the seawater to safe, low concentration sodium hypochlorite, which is re-injected into the sea chest. Water is

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treated in this way to prevent the growth of marine organisms on the FSRU seawater systems.

The temperature of the ballast water discharged from the FSRU will be ambient. Water will not remain in the ballast tanks for extended periods, and a large proportion of the ballast tanks themselves are in contact with the sea through the outer hull. Some slight heat leakage though the cargo tank insulation will reduce the ballast water temperature adjacent to the inner hull surfaces, but convection currents within the tank will cause mixing, and contact with the outer hull will ensure that ambient temperatures are maintained. In addition, due to the minimal residence time of water in the ballast tanks, dissolved oxygen levels are not expected to fall and will not be lower at the discharge point. The discharge of ballast water will occur an estimated 118 days per year, based on the delivery schedule of LNG carriers at the FSRU, with a maximum discharge volume of 17.2 MGD (62,250 m³) during LNG loading operations. No contaminants will be introduced into the ballast water system prior to discharge into the Sound.

2.5.2.3.2 LNG Carrier Ballast System

LNG carriers usually retain a small amount of ballast during the loaded voyage for trim purposes. It is unlikely that vessels will discharge any of this ballast within Long Island Sound. In any event, the water will be subject to a Ballast Management Plan as required by international regulations.

During offloading, the LNG carrier takes on ballast water through a dedicated ballast system to trim, stability, and limit hull stresses. The water intake locations differ from vessel to vessel, but typically are within the machinery space and either on the bottom of the hull or towards the bottom of the side-shell in the vicinity of the turn of the bilge. With an LNG discharge rate of 10,000 m³/hr, the LNG carrier will need to take on ballast water to maintain trim, although the LNG carriers will typically leave the FSRU at a reduced draft (i.e., with higher freeboard) than when it arrived. The total amount of ballast taken on will vary according to the ship size and the anticipated weather conditions that may be encountered on departure. For the range of potential vessels, including steam- and diesel-powered LNG carriers, a 145,000 m³ LNG carrier typically requires approximately 50,000 m³ (13.2 million gallons) of water, and a potential future 250,000 m³ carrier would require approximately 97,000 m³ (25.6 million gallons) of water to proceed on a voyage. Broadwater intends to request that all vessels limit the ballast quantities where possible and to take on any additional ballast water after leaving the Sound. While this practice will minimize the amount of ballast water taken on by the LNG carrier within the Sound; it will not eliminate the need of the LNG carrier to take on ballast while unloading.

2.5.2.3.3 LNG Carrier Water Use

It is anticipated that a majority of the LNG carriers bringing cargo to the FSRU will be steam-powered vessels. While use of steam-powered vessels significantly reduces potential air emissions, which is critical to Long Island Sound since it is considered a nonattainment area for ozone (*see* Resource Report 9, Air and Noise Quality), the use of steam-powered engines does result in increased water use for machinery cooling and

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space conditioning. Assuming that a steam-powered LNG carrier is moored at the FSRU for approximately 22 hours during the offloading process, it is estimated that approximately 57 million gallons of water will be required for cooling water purposes. Average throughput for the cooling water is estimated to be 9,756 m³/hr (2.6 million gallons/hr). Since the water will be used for cooling, the discharged cooling water will be on the order of 3.6 °F (2 • C) higher than the ambient water temperature. These cooling water intakes are typically treated with extremely low doses of sodium hypochlorite to prevent the growth of marine organisms.

Although no diesel-powered LNG carriers are currently in operation, there are dieselpowered vessels on order ranging in size up to about 215,000m³. Future concept LNG carriers could include much larger (up to 250,000 m³) carriers that could be diesel powered or use gas turbine propulsion. Since none of these larger carriers currently exist, their water usage can only be approximated. It is estimated that a future concept 250,000 m³ diesel-powered LNG carrier would be moored at the facility for approximately 32 hours during the offloading process due to the larger quantity of LNG to be offloaded. During this period, it is estimated that approximately 18.6 million gallons of water would be required for cooling water purposes. Based on the limited details that are available for these new vessels, the average seawater throughput is estimated to be 2,200 m³ per hour (582,000 gallons per hour). Other minimal water uses identified include the reliquefaction plant (660 m³ per hour, the freshwater generator (100 m³ per hour), and the side-shell water curtain (33 m³ per hour). While the water volumes for a single delivery event would increase with the larger carriers, the total annual water usage requirements would not increase appreciably since the frequency of carriers offloading would be reduced.

Regardless of the LNG carrier type, they will not discharge from their onboard wastewater treatment plant during offloading operations at the FSRU.

2.5.2.3.4 Cumulative Water Intakes

Under normal operating conditions, the cumulative average daily intake for the FSRU and LNG carriers will vary based on the number of cargos received at the FSRU each week. Taking into account all water requirements for the FSRU (i.e., ballast, desalination unit, bilge and general services pumps, and side-shell water curtain), the annual daily average intake volume for the FSRU is 5.5 MGD (20,669 m³) assuming an annual average of 118 ships per year.

The vast majority of the water usage is associated with the steam-powered LNG carriers moored at the FSRU. The annual daily intake volume required for the LNG carriers, accounting for ballast and cooling water circulation, is 22.7 MGD (85,930 m³).

In comparison, existing power plants on Long Island Sound consistently take in a volume of water that is an order of magnitude higher. The Keyspan Northport and Port Jefferson facilities are permitted to withdraw 938 MGD (3.6 million m³) and 398 MGD (1.5 million m³), respectively (Fuchs 2005). Five facilities in Connecticut have been identified that withdraw significantly greater volumes of water than the Project would.

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The Millstone nuclear power plant is permitted to withdraw approximately 1.5 BGD (5.6 million m³); the PSEG Power facilities in New Haven and Bridgeport are permitted to withdraw 410 MGD (1.5 million m³) and 152 MGD (0.6 million m³), respectively; the NRG Norwalk facility is permitted to withdraw 312 MGD (1.2 million m³); and the Bridgeport Energy facility is permitted to withdraw 168 MGD (0.6 million m³) (Mauger 2005). Each of these facilities requires water intakes and discharges to and from more environmentally sensitive nearshore waters, while Broadwater will withdraw water from the central part of the Sound.

Daily intake values for the FSRU and LNG carrier represent an insignificant fraction of the total volume of water in the Sound. The Sound contains approximately 18 trillion gallons of water. The combined water taken in by the FSRU and LNG carriers on a daily basis is less than 0.00016% of the total volume of water in Long Island Sound. Based on the comparative intake volumes of water, which are insignificant when compared to the total volume of water in the Sound, coupled with the constant recirculation of Sound waters due to tidal and wind action, impacts on water quality will not occur from any intake operations. With respect to water physically removed from the Sound, only ballast water taken on by the LNG carriers will be exported out of the Sound. This total volume is estimated at 4.3 MGD. Potential impacts on marine life from water intakes are discussed in Resource Report 3, Fish, Vegetation, and Wildlife.

2.5.2.4 FSRU Discharges

Operation of the FSRU will result in up to seven point-source discharges into the Sound, including:

- Two ballast water discharge points (port and starboard) located approximately 3 feet (1 m) below the water line;
- One wastewater discharge point (either port or starboard) located approximately 3 feet (1 m) below the water line;
- One desalinization overboard (starboard) located approximately 13 feet (4 m) below the water line;
- One seawater cooling discharge (port) located approximately 13 feet (4 m) below the water line;
- One IG scrubber cooling pump overboard (starboard) located approximately 3 to 6 feet (1 to 2 m) below the water line; and
- One emergency bilge overboard (port) located approximately 13 feet (4 m) below the water line.

If wastewater cannot be effectively treated to comply with New York State discharge requirements, then black and gray water will be routed to holding tanks and shipped to shore for disposal at an approved treatment facility. The emergency bilge overboard is

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not discussed in detail, as Broadwater does not anticipate any discharge through this overboard for the lifespan of the Project.

FSRU operations also will include three non-point-source discharges into the Sound, including:

- One side-shell water curtain to discharge treated seawater between the FSRU and any moored LNG carrier as a hull integrity measure during offloading operations;
- Uncontaminated deck runoff from storm events; and
- Fire-water bypass system water.

Since all discharges are anticipated to meet NYSDEC discharge requirements for contaminant levels and other physical water quality parameters, the need for an extensive mixing zone analysis was not pursued.

As indicated in Section 2.5.2.2, most discharges from the FSRU will have a low residual sodium hypochlorite concentration. Sodium hypochlorite concentrations will be monitored through sampling of overboard water collected from internal FSRU systems before it is discharged to the Sound. The chlorine concentrations of samples will be determined through a colorimetric assay. The production and injection rate of the sodium hypochlorite added to the system at the sea chest will be adjusted as necessary.

Ballast Water System

As discussed above, the discharge of ballast water will occur 118 days per year based on the delivery schedule of LNG carriers at the FSRU, with a maximum discharge volume of 17.2 MGD (62,250 m³) during offloading operations. No contaminants will be introduced into the ballast water system prior to discharge into the Sound.

Treated Wastewater from the Onboard Treatment Plant

Based on the current design, the FSRU will be equipped with a membrane bioreactor (MBR) with the capability of treating both blackwater and greywater discharges. Based on the typical specifications for an MBR, it is anticipated that the discharge will comply with NYSDEC discharge standards. However, if it is determined that, based upon review and consideration by NYSDEC during the SPDES evaluation process, the discharges will not comply with applicable regulations, all blackwater and graywater generated by systems on the FSRU (e.g., sinks, shower drains, and floor drains) that may contain increased levels of detergents and nutrients will be routed to a holding tank and shipped to shore for disposal at an approved facility.

The discharge from the MBR, which would be located approximately 3 feet (1 m) below the water line, is anticipated to be approximately 2,000 to 5,000 gallons per day (8 to 19 m³/d). The MBR provides an advanced treatment process that produces a discharge of much higher quality than a USCG treatment device, and it provides Broadwater with the

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ability to be consistent with the Long Island Sound Comprehensive Conservation and Management Plan.

A typical USCG treatment device can achieve the following effluent quality standards:

Suspended solids: 150 mg/L; and
Fecal coliform: 200 counts/100mL.

Biological oxygen demand, pH, and chlorine are not parameters typically addressed by treatment in this type of system.

The MBR system proposed by Broadwater produces a much higher effluent quality and addresses more water quality parameters than a USCG treatment device. The MBR effluent quality standards include:

• Suspended solids: 3.1 mg/L;

• Biological oxygen demand: 2.6 mg/L;

• Fecal coliform: 10.6 counts/100mL;

pH within acceptable limits for the original water source; and

• Chlorine: 0 μg/L.

Discharge from the MBR will be tested weekly using an assay for the most probable number (MPN) of viruses. The sample for this assay will be collected from the internal FSRU treatment system and sent off site for analysis. In addition, water quality monitoring plans will be prepared and implemented to ensure adherence to discharge standards in accordance with NYSDEC requirements as determined during the SPDES permitting process (*see* correspondence with NYSDEC presented in Appendix A).

Desalination Unit Overboard

The desalination unit overboard will be used to discharge water generated by the desalination unit, which will be used to make potable water onboard the FSRU. The approximate volume of this discharge is 0.6 MGD (2,355 m³/d). The discharge will be comprised of seawater that had been taken in by sea chest, but with a slight salinity increase of approximately 2%. This equates to a salinity increase of less than 0.5 ppt which is not significant and not likely measurable since salinity values in the Sound range from 24 to 25 ppt. Based on these values, no impacts on water quality will occur.

Central Cooling Water (Non-Routine Operations Only)

The central cooling water overboard will be used only if the FSRU's glycol/water system fails. The actual capacity of the cooling water system, and the associated discharges, will be determined during the final design stage of the Project. While this system will have a permitted discharge point, no discharge will occur under routine operating conditions. The seawater used for cooling will not come into direct contact with machinery onboard the FSRU. Therefore, no impacts on water quality will occur.

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Inert Gas (IG) Scrubber Overboard

The IG scrubber is used only infrequently when a cargo tank needs to be purged for cleaning and/or inspection. The use of the IG scrubber would occur approximately once every 5 years. Water from the sea chest is used to "clean" and cool the inert gas stream used to purge the tanks. Water usage is estimated to be approximately 290,000 gallons/hr (1,100 m³/hr), with a total of approximately 11.6 million gallons (44,000 m³) required for a single purge of the entire FSRU.

Side-Shell Water Curtain

To maintain hull integrity of the FSRU and LNG carrier, a constant curtain of water will be directed overboard during LNG transfer from the carrier to the FSRU. Both the FSRU and the LNG carrier will generate side-shell water curtains. This discussion is limited to the curtain generated by the FSRU. Discharges volumes from the LNG carrier are included in the volumes discussed in Section 2.5.2.3.3.

This water will be supplied by the two sea chest intakes and thus will contain residual chlorine levels. The side-shell water curtain will discharge directly into the Sound between the FSRU and the LNG carrier. It is anticipated that water from the side shell water curtain will be discharged at an approximate rate of 8,718 gallons/hr (33 m³/hour). Discharges from the side-shell water curtain will occur for an estimated 118 days per year and will be at ambient temperature.

Increases in side-shell curtain water will occur during offloading by larger LNG carriers (up to future concept 250,000 m³) since the offloading time will increase. For example, a 145,000 m³ LNG carrier will require approximately 15 hours for cargo transfer. The side-shell curtain will also be operational for a minimal time before and after the actual cargo transfer. For larger carriers, the side-shell water curtain discharge is expected to occur at similar discharge rates. As with the ballast water discharge, minimal residual chlorine (0.01 to 0.05 ppm) will be present in the water curtain discharge, which will not impact water quality in the Sound.

Drainage Systems and Deck Runoff

The fire-water bypass system will not be treated with sodium hypochlorite. Seawater for this system will be utilized only in the event of a fire onboard the FSRU (or testing of the fire-water system) and will be supplied by seawater intakes that are independent of the main seawater intake system. Discharge during any testing of the fire-water bypass system will be overboard via scupper drains, which will return the seawater directly back to the Sound. The volume of water to be used for testing is estimated to be 0.74 million gallons (2,800 m³), and the testing will occur only once a month. Runoff from the testing of the fire-water system will not impact the temperature, salinity, or dissolved oxygen content of water in the Sound.

Uncontaminated storm water runoff from the FSRU will be comprised of rainwater and will be directed overboard via scupper drains. The volume of this runoff will be based on local levels of precipitation and will be at ambient temperature when drained to the Sound. Runoff from any on-deck location that has the potential for oil and grease

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contamination will be collected and routed to the bilge holding tank for shipment to shore.

Spill Potential

The potential exists for spills of various materials from the FSRU that could enter Long Island Sound and impact water quality. Materials stored on the FSRU with spill potential include aqueous ammonia, ethylene glycol, diesel fuel, and mercaptan (used as a natural gas odorant). Diesel fuel will be stored in tanks integrated into the hull of the FSRU, and the ethylene glycol is restricted to a closed-loop system, minimizing spill potential. The aqueous ammonia and mercaptan will be transported and stored in isotanks with adequate containment to minimize impacts. There is also the potential for a spill of LNG to result in short-term localized impacts. The effects of the LNG spill would likely be limited to the water surface and a limited portion of the upper water column in the vicinity of the FSRU. The impacts of such a spill would include temporary changes in the thermal characteristics of the affected area. For more detail on impacts on marine resources, *see* Resource Report No. 3 (Fish, Vegetation, and Wildlife), Section 3.2.2.2.

These substances are discussed in more detail in Resource Report No. 11 (Safety and Reliability), Section 11.3.2.3. In accordance with SPCC regulations and the proposed revisions to the SPCC Rule (December 2005), facilities that become operational after August 18, 2006, must prepare and implement an SPCC Plan before beginning operations. Broadwater recognizes this requirement and, prior to FSRU and pipeline operations in 2010, will prepare and submit a Project-specific SPCC Plan in order to address the potential for spills of substances stored and utilized on the FSRU. The SPCC Plan will describe preventive and response measures that will be implemented in the event of a spill.

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APPENDIX A



A-1 PUBLIC

From: Jeff Gregg [jagregg@gw.dec.state.ny.us]
Sent: Tuesday, April 05, 2005 10:39 AM

To: Allen-Mochrie, Sara

Cc: Donnelly, Mike; Charles deQuillfeldt; Diane English; Karen Woodfield; William Little Subject: Re: Response to Comments and Revised Sampling and AnalysisPlan - Broadwater

Sara - We have reviewed your responses to our comments and the resulting revised sampling and analysis plan and are satisfied with both of them.

We have no further comments. Thank you.

>>> "Allen-Mochrie, Sara" <SAllen-Mochrie@ene.com> 04/01/05 06:53PM >>>

<code><<NYSDEC</code> Respons to Comments on Broadwater SAP $4_1_05.pdf>> <<R3_Broadwater LI Sound SAP draft final <math display="inline">2_NYSDEC.pdf>>$

Jeff,

Attached please find E&E's response to comments received for the Broadwater sampling and analysis plan and a revised version of the plan that includes the comment responses.

Please feel free to contact me if you have any questions about the attachments.

Thanks, Sara

Sara L. Allen-Mochrie Senior Biologist Ecology & Environment, Inc. 368 Pleasantview Drive Lancaster, NY 14086 (716) 684-8060 work (716) 684-0844 fax (716) 984-0349 cell sallen-mochrie@ene.com

Memorandum



Date: October 17, 2005

To: Mike Donnelly

From: Sara Allen-Mochrie

Subject: Call to Alan Fuchs at NYSDEC

I spoke to Alan Fuchs who is the Wastewater Permits Section, South Region 1-3, Section Chief (518-402-8238) on October 14, 2005 regarding discharges for the Broadwater project. Two questions were outstanding that needed input from NYSDEC including:

- •• Adherence to water quality standards when guidance values are lower than the ambient water conditions, and
- •• The correct evaluation of mixing zones.

Mr. Fuch's first off the cuff response regarding adherence to water quality standards is that discharges would most likely need to be returned to ambient conditions. This is often the case for physical water quality parameters such as total dissolved solids, but not the practice for chemical constituents such as dissolved metals. He directed me to the New York State regulations for effluent limitation (NYCRR 702.17 Variances to Effluent Limits Based on Standards and Guidance Values). This regulation lays out situations in which a variance to a specific effluent limitation may apply and how a permittee demonstrates that achievement of a certain effluent limitation is not feasible. If approved, this process results in a variance for that effluent limit in one given discharge for that permittee only.

Mr. Fuch's second response regarding the correct evaluation of mixing zones is that preparation of a simple model is sufficient as long as ample information is provided on the volume of material and the assimilative capacity of the water body. This applies to simple discharges only. If more information needs to be provided, it will be based on further evaluations that are performed by two different groups at NYSDEC. These groups are the biologists from a water quality perspective and engineers from a technology based perspective. The final permit review and determination of adequate information may be performed by one or both groups.

APPENDIX B ARCHIVE OF EMAIL APPROVAL USACE MIKE3 MODEL

B-1 PUBLIC

From:

Weaver, Laurie

Sent:

Friday, June 10, 2005 11:47 AM

To:

'Russell Smith (E-mail)'

Subject:

FW: Broadwater Sediment Modeling Protocol

Attachments:

Water Quality Modeling_Protocol_042905_SAL.pdf

Russell.

We have completed our sampling efforts in Long Island Sound and are initiating our modeling efforts. Do you have any comments or questions regarding the sediment modeling protocol that was forwarded on May 2, 2005?

Thank you.

Laurie

----Original Message----

From:

Weaver, Laurie

Sent:

Monday, May 02, 2005 10:05 AM

To:

Jeff Gregg (E-mail); Jeff Zappieri (E-mail); 'Lingnard Knutson (knutson.lingard@epa.gov)'; 'russell.c.smith@usace.army.mil'

Cc:

Sandra Barnett (E-mail); Donnelly, Mike; John Duschang (E-mail); 'slowe@lmseng.com'; Allen-Mochrie, Sara

Subject:

Broadwater Sediment Modeling Protocol

Good morning,

Attached for your review and comment, is the sediment modeling protocol that Broadwater is proposing for use in estimating potential sediment fate and transport and potential water quality impacts during construction of the Broadwater project. I would be more than happy to answer any questions that you have and to receive comments.

Regards,

Laurie Weaver



Water_Quality_Mod eling_Protoco...

Laurie K. Weaver

Ecology and Environment, inc. Buffalo Corporate Center 368 Pleasant View Drive Lancaster, N Y 14086

Phone: (716) 684 - 8060 Fax: (716) 684 - 0844 http:\\www.ene.com

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International Specialists in the Environment

BUFFALO CORPORATE CENTER 368 Pleasant View Drive, Lancaster, New York 14086 Tel: (716) 684-8060, Fax: (716) 684-0844

CONTACT REPORT

Meeting [] Telephone [X] Other []

ORGANIZATION:

USACE NY District

ADDRESS:

PHONE NO.:

917 790-8519

PERSON

CONTACTED:

Russell Smith

TO:

Mike Donnelly, Mike Kane

FROM:

Laurie Weaver

DATE:

June 14, 2005

RE:

Sediment Modeling Protocol

XC:

I spoke with Russell Smith who confirmed that he had no comments on the Broadwater Sediment Modeling Protocol forwarded to him on May 2, 2005. He indicated that as long as NYSDEC is on board, he has no concerns.

© Ecology and Environment, Inc

From:

Weaver, Laurie

Sent:

Monday, May 02, 2005 10:05 AM

To:

'Jeff Gregg (E-mail)'; 'Jeff Zappieri (E-mail)'; 'Lingnard Knutson (knutson.lingard@epa.gov)';

'russell.c.smith@usace.army.mil'

Cc:

'Sandra Barnett (E-mail)'; Donnelly, Mike; 'John Duschang (E-mail)'; 'slowe@lmseng.com';

Allen-Mochrie, Sara

Subject:

Broadwater Sediment Modeling Protocol

Attachments:

Water Quality_Modeling_Protocol_042905_SAL.pdf

Good morning,

Attached for your review and comment, is the sediment modeling protocol that Broadwater is proposing for use in estimating potential sediment fate and transport and potential water quality impacts during construction of the Broadwater project. I would be more than happy to answer any questions that you have and to receive comments.

Regards,

Laurie Weaver



Water_Quality_Mod eling_Protoco...

Laurie K. Weaver

Ecology and Environment, inc. Buffalo Corporate Center 368 Pleasant View Drive Lancaster, N Y 14086 Phone: (716) 684 - 8060

Fax: (716) 684 - 0844 http://www.ene.com lweaver@ene.com

From:

Jeff Gregg [jagregg@gw.dec.state.ny.us]

Sent:

Thursday, May 05, 2005 10:37 AM Weaver, Laurie; Donnelly, Mike

To: Cc:

jzappier@dos.state.ny.us; Allen-Mochrie, Sara; knutson.lingard@epa.gov; Charles deQuillfeldt; Diane English; Karen Woodfield; William Little; jduschang@lmseng.com;

slowe@Imseng.com; sandra_barnett@transcanada.com; russell.c.smith@usace.army.mil

Re: Broadwater Sediment Modeling Protocol Subject:

Laurie and Mike -

The proposed sediment modeling protocol you submitted is acceptable. As we have in the past, we will be requiring monitoring during construction to compare findings with the modeling results. Thanks.

Jeff

>>> "Weaver, Laurie" <LWeaver@ene.com> 5/2/2005 10:04:54 AM >>> Good morning,

Attached for your review and comment, is the sediment modeling protocol that Broadwater is proposing for use in estimating potential sediment fate and transport and potential water quality impacts during construction of the Broadwater project. I would be more than happy to answer any questions that you have and to receive comments.

Regards,

Laurie Weaver

<<Water Quality Modeling Protocol_042905_SAL.pdf>>

Laurie K. Weaver Ecology and Environment, inc. Buffalo Corporate Center 368 Pleasant View Drive Lancaster, N Y 14086 Phone: (716) 684 - 8060 (716) 684 - 0844 Fax:

http://www.ene.com

lweaver@ene.com

From: Sent: Knutson.Lingard@epamail.epa.gov Monday, May 09, 2005 3:23 PM

To:

Weaver, Laurie

Cc:

Jeff Gregg (E-mail); John Duschang (E-mail); Jeff Zappieri (E-mail); Donnelly, Mike;

russell.c.smith@usace.army.mil; Allen-Mochrie, Sara; Sandra Barnett (E-mail);

slowe@lmseng.com

Subject:

Re: Broadwater Sediment Modeling Protocol

Laurie,

Thanks for the opportunity to review the Sediment Modeling Protocol. Our dredging team has revewed the model and finds it appropriate for use in this project.

Lingard Knutson

From:

Weaver, Laurie

Sent: To:

Monday, May 09, 2005 4:44 PM 'Knutson.Lingard@epamail.epa.gov'

Subject:

RE: Broadwater Sediment Modeling Protocol

Lingard,

Thank you for your review and response.

Laurie

----Original Message----

From: Knutson.Lingard@epamail.epa.gov [mailto:Knutson.Lingard@epamail.epa.gov]

Sent: Monday, May 09, 2005 3:23 PM

To: Weaver, Laurie

Cc: Jeff Gregg (E-mail); John Duschang (E-mail); Jeff Zappieri (E-mail); Donnelly, Mike;

russell.c.smith@usace.army.mil; Allen-Mochrie, Sara; Sandra Barnett (E-mail);

slowe@lmseng.com

Subject: Re: Broadwater Sediment Modeling Protocol

Laurie,

Thanks for the opportunity to review the Sediment Modeling Protocol. Our dredging team has revewed the model and finds it appropriate for use in this project.

Lingard Knutson

APPENDIX C CADMIUM CLARIFICATION MEMO

C-1 PUBLIC

Memorandum



Date: November 4, 2005

To: Jeff Gregg

From: Sara Allen-Mochrie and Mike Donnelly

Subject: Sediment Sampling Results - Cadmium

In response to a comment received from NYSDEC regarding cadmium results for the Spring 2005 Environmental Sampling Report for the Broadwater project, cadmium was not detected in any sediment samples collected during this field program. The results reported in Table 2-2 of the Environmental Sampling Report are only the positive analytical results for the sediment samples and did not list analytes if a concentration was not detected.

Confusion may have occurred between Table 2-2 in the report and Table 1 in Appendix B since these are the same table in two different formats with slightly different titles. Again, they both only contain metals for which a positive result was found in at least one sample.

There are 5 metals that are not reported in these tables since there were no positive results for these analytes in any sediment sample analyzed. These metals include:

- Antimony
- · · Cadmium
- · · Selenium
- Silver
- · Thallium

The results for these 5 metals are summarized in the attached Table 1 which lists the analytes reported non-detect concentration, which is the PQL for that sample.

Broadwater Environmental Sampling Report Table 1: Summary of Non-Detect Results for Metals in Sediment Samples, May 2005

Sample II)
-----------	---

Analyte	C-1	C-2	C-3	C-3D	C-4	C-4D	IC-5	IC-6	IC-7	MG-5	MG-3	IC-13	IC-14	C-15	C-16	C-16D	C-17	C-18	C-19	C-20	C-21	C-22	C-23	C-24	C-25	C-26	C-27	C-28
Metals (ppm)																												
Antimony	14.1 U	8.3 U	11.0 U	11.7 U	14.0 U	12.2 U	20.1 U	9.1 U	12.0 U	8.6 U	9.7 U	18.8 U	20.7 U	10.1 U	11.4 U	11.5 U	13.2 U	9.7 U	8.9 U	9.5 U	16.3 U	21.9 U	14.5 U	13.5 U	14.1 U	14.0 U	13.1 U	11.7 U
Cadmium	0.19 U	0.11 U	0.15 U	0.16 U	0.19 U	0.16 U	0.27 U	0.12 U	0.16 U	0.11 U	0.13 U	0.25 U	0.28 U	0.13 U	0.15 U	0.15 U	0.18 U	0.13 U	0.12 U	0.13 U	0.22 U	0.29 U	0.19 U	0.18 U	0.19 U	0.19 U	0.17 U	0.16 U
Selenium	3.8 U	2.2 U	2.9 U	3.1 U	3.7 U	3.3 U	5.4 U	2.4 U	3.2 U	2.3 U	2.6 U	5.0 U	5.5 U	2.7 U	3.0 U	3.1 U	3.5 U	2.6 U	2.4 U	2.5 U	4.3 U	5.8 U	3.9 U	3.6 U	3.8 U	3.7 U	3.5 U	3.1 U
Silver	0.47 U	0.28 U	0.37 U	0.39 U	0.47 U	0.41 U	0.67 U	0.30 U	0.40 U	0.29 U	0.32 U	0.63 U	0.69 U	0.34 U	0.38 U	0.38 U	0.44 U	0.32 U	0.30 U	0.32 U	0.54 U	0.73 U	0.48 U	0.45 U	0.47 U	0.47 U	0.44 U	0.39 U
Thallium	5.6 U	3.3 U	4.4 U	4.7 U	5.6 U	4.9 U	8.1 U	3.6 U	4.8 U	3.4 U	3.9 U	7.5 U	8.3 U	4.0 U	4.6 U	4.6 U	5.3 U	3.9 U	3.6 U	3.8 U	6.5 U	8.8 U	5.8 U	5.4 U	5.6 U	5.6 U	5.2 U	4.7 U

Key: U = Not detected at the reported value

Ecology & Environment, Inc.

-1-

	* * *		
INORGANIC	ANALYSIS	DATA	SHEET

	DANCE	1111	мо.		
_				 	_
(2-15				

Contract: NY

NY04-648

Lab Code: STLBFLO

Case No.:

SAS No.:

SDG NO.:

BRD5

Matrix (soil/water):

SOIL

Lab Sample ID:

AD524919

Level (low/med):

LOW

Date Received:

4/28/2005

% Solids: 72

Concentration Units (ug/L or mg/kg dry weight):

MG/KG

CAS No.	Analyte	Concentration	С	Q	м
7429-90-5	Aluminum	5240	1	E	P
7440-36-0	Antimony	10.1	שׁ	1	P
7440-38-2	Arsenic	4.2		1	P
7440-39-3	Barium	15.3		1	P
7440-41-7	Beryllium	0.26]	P
7440-43-9	Cadmium	0.13	ט	1	P
7440-70-2	Calcium	1700		E	P
7440-47-3	Chromium	14.2	1		P
7440-48-4	Cobalt	4.4			P
7440-50-8	Copper	18.3	T		P
7439-89-6	Iron	10000	1	E	P
7439-92-1	Lead	2 9.6]	P
7439-95-4	Magnesium	3500		ĮΕ	₽
7439-96-5	Manganese	175	T	E	P
7440-02-0	Nickel	8.6		1	P
7440-09-7	Potassium	1670		E	P
7782-49-2	Selenium	2.7	ש		P
7440-22-4	Silver	0.34	ש	1	P
7439-97-6	Mercury	0.036	1		cv
7440-23-5	Sodium	3680]	P
7440-28-0	Thallium	4.0	ש	j	P
7440-62-2	Vanadium	14.1		1	P
7440-66-6	Zinc	41.5		1	P

Color Before:	BROWN	Clarity Before:	CLOUDA	Texture:	TOPSOIL
Color After:	BROWN	Clarity After:	CLDY/FI	Artifacts:	
Comments:					
_					

Ecology & Environment. Inc.

-1-

INORGANIC ANALYSIS DATA SHEET

SAMPLE	NO.		
C-16			
C-T0			

Contract: NY04-648

Lab Code: STLBFLO

STLBFLO Case No.:

SAS No.:

SDG NO.:

BRD5

Matrix (soil/water):

SOIL

Lab Sample ID:

AD524917

Level (low/med):

LOW

Date Received:

4/28/2005

% Solids: 64

Concentration Units (ug/L or mg/kg dry weight):

MG/KG

	•				
CAS No.	Analyte	Concentration	С	Q	M
7429-90-5	Aluminum	6810		E	P
7440-36-0	Antimony	11.4	שׁ	1	P
7440-38-2	Arsenic	5.9		1 :	P
7440-39-3	Barium	18.8		1	P
7440-41-7	Beryllium	0.33		1	P
7440-43-9	Cadmium	0.15	שׁ	Ī	P
7440-70-2	Calcium	2580		E	P
7440-47-3	Chromium	14.5			P
7440-48-4	Cobalt	5.9]	P
7440-50-8	Copper	6.2			P
7439-89-6	Iron	13900]E	P
7439-92-1	Lead	4.6			P
7439-95-4	Magnesium	4900		E	P
7439-96-5	Manganese	244	Ī	E	P
7440-02-0	Nickel	11.1		1	P
7440-09-7	Potassium	2220		E	P
7782-49-2	Selenium	3.0	Ū		P
7440-22-4	Silver	0.38	ש	I	P
7439-97-6	Mercury	0.020			cv
7440-23-5	Sodium	4550] .	P
7440-28-0	Thallium	4.6	ש	1	P
7440-62-2	Vanadium	18.4	1	Ī	P
7440-66-6	Zinc	28.9	l	I	₽

Color Before:	BROWN	Clarity Before:	CLOUDY	Texture:	TOPSOIL
Color After:	BROWN	Clarity After:	CLDY/FI	Artifacts:	
Comments:					
·					
	·				

Ecology & Environment. Inc.

-1-INORGANIC ANALYSIS DATA SHEET

	SAMPLE	NO.
_	1 1 5	

Contract:

NY04-648

Lab Code: STLBFLO Case No.:

SAS No.:

SDG NO .:

BRD5

Matrix (soil/water):

SOIL

Lab Sample ID:

AD524918

Level (low/med):

LOW

Date Received:

4/28/2005

% Solids: 60

Concentration Units (ug/L or mg/kg dry weight):

CAS No.	Analyte	Concentration	С	Ď	М
7429-90-5	Aluminum	8360		E	P
7440-36-0	Antimony	11.5	ש		P
7440-38-2	Arsenic	7.6		[P
7440-39-3	Barium	23.2			P
7440-41-7	Beryllium	0.42	1		P
7440-43-9	Cadmium	0.15	. U		P
7440-70-2	Calcium	2650		E	P
7440-47-3	Chromium	18.3	1	1	P
7440-48-4	Cobalt	6.7			₽
7440-50-8	Copper	11.7			P
7439-89-6	Iron	16300		E	P
7439-92-1	Lead	7.4		1	P
7439-95-4	Magnesium	5560		E	P
7439-96-5	Manganese	249		E	P
7440-02-0	Nickel	13.6			P
7440-09-7	Potassium	2700	1	E	P
7782-49-2	Selenium	3.1	U		P
7440-22-4	Silver	0.38	ש		P
7439-97-6	Mercury	0.017	ס		cv
7440-23-5	Sodium	6010	1		P
7440-28-0	Thallium	4.6	ש		P
7440-62-2	Vanadium	23.1			P
7440-66-6	Zinc	42.5	1		P

Color Before:	BROWN	Clarity Before:	CLOUDY	Texture:	TOPSOIL
Color After:	BROWN	Clarity After:	CLDY/FI	Artifacts:	
Comments:					,

APPENDIX D GENERIC SPCC PLAN

D-1 PUBLIC

Generic Spill Prevention Control and Countermeasures Plan for the Broadwater Subsea Pipeline Construction

Long Island Sound

December 2005

This is a generic spill prevention control and countermeasure (SPCC) plan intended to describe the basic spill prevention and response measures that will be used by Broadwater during construction of the subsea pipeline. A site-specific SPCC plan that meets the requirements of 40 Code of Federal Regulations 112 will be completed before commencement of construction once specific construction equipment and refueling areas are identified.

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Authorized Facility Representative:

Management Approval and Review [112.5 & 112.7(D)(2)]

MANAGEMENT APPROVAL

Broadwater is committed to the prevention of discharges of oil or hazardous materials to navigable waters or the environment. This spill prevention control and countermeasures (SPCC) plan is for activities related to the construction of a new 30-inch diameter subsea natural gas pipeline. The constructions consists of a 22 mile (35 km) segment of natural gas pipeline located approximately 9 miles (14.5 km) from the shore of Long Island in New York State waters. This pipeline is a component of the Broadwater project, a proposed LNG terminal that will consist of a floating storage and regasification unit (FSRU). If a spill occurs, Broadwater will provide the manpower, equipment, and materials required to expeditiously control and remove any quantity of discharged oil that may be harmful to waterways or the environment.

Signatu);
Tit	»:
Profession	I Engineer's Review [112.3(D)(1)]
Chapter 40 of the Code of Fed supervised pipeline construct Engineer attests that this SPCC practices, including applicable	rofessional Engineer is familiar with the requirements of eral Regulations Part 112 (40 CFR 112) and has previously on activities. The undersigned Registered Professional plan has been prepared in accordance with good engineering industry standards, and in accordance with the requirements is adequate for the construction activities.
Signature	Name
Title	Company
Date	P.E. Registration Number
	4

1 Introduction

1.1 Purpose

The purpose of this spill prevention control and countermeasure (SPCC) plan is to prevent oil spills or hazardous material releases from occurring, and to perform safe, efficient, and timely response activities in the event of a spill or leak (both referred to as *spills* herein). In accordance with United States Environmental Protection Agency (EPA) oil pollution prevention regulations (40 Code of Federal Regulations [CFR] 112), Broadwater must prepare and implement an SPCC plan for facilities that could reasonably be expected to discharge oil into or upon navigable waters or adjoining shorelines.

EPA's definition of a *facility* includes any mobile installation, equipment, or pipeline (other than a vessel) in which oil will be used. This SPCC plan is required if the storage or use of oil at the job site is greater than 1,320 gallons. The boundaries of the job site covered by this SPCC plan will depend on site-specific factors such as equipment used, types of activities at the site, and staging and fueling areas. This generic SPCC plan provides an overview of the project and proposed construction activities.

This generic SPCC plan will be revised into a site-specific SPCC plan once the construction contractor and construction project scope of work (including equipment, materials, and activities) is known. The revised SPCC plan will be a site-specific comprehensive plan to prevent, respond to, and report spills or releases to the environment. The plan will be designed to minimize hazards to human health and/or the environment from any sudden or non-sudden releases of oils or toxic, hazardous, or other polluting materials to the air, soil, surface water, or groundwater.

1.1.1 Using the Plan

In addition to satisfying regulatory requirements, this SPCC plan will be used as a working document throughout the pipeline construction period. The plan should be used frequently in the following ways:

- As a reference for oil storage, refueling, and containment system information;
- As an employee training guide for preventing and responding to spills; and
- As a resource during an emergency response.

1.1.2 Plan Revisions

The SPCC plan will be updated as project work progresses or as site activities change. An updated copy of this SPCC plan will be maintained at the construction site(s).

1.2 Site Information [112.7(a)(3)]

1.2.1 Construction Location

This SPCC plan was developed for the construction of the Broadwater Pipeline, a 22 mile (35 km) pipeline segment that will be installed beneath the seafloor of Long Island Sound from the FSRU mooring structures as an interconnection location at the existing 24-inch diameter section of the IGTS pipeline which lies approximately 22 miles (35 km) west of the proposed FSRU site in Long Island Sound.

The pipeline begins at the FSRU mooring structure and continues west following a subsea route for the entire length of the pipeline with no crossings of land or shoreline areas. A route map is shown in Figure 1-1. Operations covered by this SPCC plan include all construction activities associated with the pipeline.

In the site-specific SPCC plan, Broadwater will include a description of the equipment that will be used, staging areas, and fueling operations that will occur during construction.

1.2.2 Waterways

Pipeline construction activities will occur entirely within Long Island Sound, which is adjacent to and flows directly into the Atlantic Ocean. Personnel working on the construction of the Broadwater Pipeline will be made aware that spills on the construction site(s) can impact these waterbodies, which could then affect marine environments in Long Island Sound, adjacent shoreline areas and potentially the Atlantic Ocean.



Source: ESRI StreetMap, 2002.

Figure 1-1
Proposed Broadwater Project
Location in Long Island Sound

2 Potential Spill Sources and Spill Prevention Control and Countermeasure Features

2.1 Spill Prevention Control and Countermeasure Compliance [112.7(a)(1) & 112.7(a)(2) & 112.8]

2.1.1 Potential Spill Sources

Potential spill sources at the construction site include materials and equipment brought on site, which are likely to include:

- Equipment staging and maintenance areas (fuel, lubricating oil, and hydraulic oil from the drill rig, backhoes, bulldozers, piling drivers, water trucks, pickup trucks, support truck equipment, lighting units, pumps, and generators);
- Fuel staging areas (bulk storage of gasoline and diesel);
- Hazardous material staging areas (containers of lubricants, fuels, and hydraulic oil); and
- Waste storage areas (drums of used oil, filters, and material used to clean and maintain equipment).

Once a contractor is chosen, this generic SPCC plan will be revised to include a description of the oil storage, handling, and containment features at the construction site.

2.1.2 Equipment Staging and Fueling Area

After the construction contractor is selected, the staging area for heavy equipment and any necessary smaller portable equipment (generators, pumps, and light units) will be identified (Table 2-1). At that time, fueling or hazardous material storage areas will be identified and this SPCC plan will be revised (project-specific plans will be incorporated).

Table 2-1
List of Items at the Construction Site

Equipment or Materials Stored on Site	Quantity on Site
	Fuel/Lubrication -
	Hydraulic Oil -
	Other -
	Fuel/Lubrication -
	Hydraulic Oil -
	Other -
	Fuel/Lubrication -
	Hydraulic Oil -
	Other -

Table 2-1 **List of Items at the Construction Site**

Mobile Equipment Brought and Used on Site	Quantity on Site
	Fuel/Lubrication -
	Hydraulic Oil -
	Other -
	Fuel/Lubrication -
	Hydraulic Oil -
	Other -
	Fuel/Lubrication -
	Hydraulic Oil -
	Other -

3 Spill Prevention and Response

3.1 Spill Containment Methods [112.7(a)(3) & 112.8]

Contractors will be trained to implement spill prevention practices for work with and around oil sources. Contractors will rely on standard spill prevention practices at all times to minimize the potential for an oil release.

This section identifies the types of secondary containment or diversionary structures that will be used to handle each spill source identified in Section 2.1.1:

- Equipment Staging and Maintenance Areas. Equipment leaks from fuel tanks, equipment seals, or hydraulic lines will be contained in a spill pad placed beneath potential leak sources. A temporary berm will contain any leaks from parked equipment;
- Fuel Staging Areas. Spills during fueling operations will be contained within pallets for small container handling, or secondary containment berms in the bulk fuel storage areas. A funnel and/or hand pump will be used to transfer fuel into portable equipment, and a spill pad will be used to absorb incidental spills or drips. Drum leaks will be repaired with a patch kit. A spill response kit will be located near the fueling area for easy access. The kit will include plastic sheeting, tarps, overpack drums, kitty litter, shovels, and assorted absorbent pads;
- Hazardous Material Staging Areas. Container or drum spills in the hazardous material staging areas will be stored or contained within pallets; and
- Waste Storage Areas. Containment for storage areas that will hold more than six 55-gallon drums will include polyethylene (10 mil) lined earthen berms. Smaller areas storing fewer than six 55-gallon drums will use containment as described above or a portable manufactured rack with a containment feature.

3.2 Emergency Response [112.7(a)(3)(iv) & 112.7(c)]

It is critical to initiate spill response and notification immediately following or as soon as there is knowledge of a spill to minimize human health and environmental impacts, and to minimize property damage and cleanup costs. Notification of a discharge will be made in accordance with 33 CFR 153, Subpart B, and 40 CFR 302. See Section 3.5 for notification procedures.

Contractors will be trained to respond immediately to spills of regulated materials. The standard approach toward spill response is as follows.

In the event of a spill, the following steps will be taken:

Assess Hazard

- Cease activities that are causing or are in the vicinity of the leak.
- If possible, secure the source to stop the leak or spill of additional material.
- Notify the Broadwater construction superintendent, or if not available, the environmental inspector.
- Complete the Spill Notification Form.

Obtain Spill Response and Personal Protective Equipment

- Direct safe evacuation of the area, and notify the fire department (911) and emergency response contractor, if necessary.
- Secure the area.
- Obtain appropriate spill response equipment and personal protective equipment (PPE).

Contain and Eliminate Spill Source

- Contain the spill to prevent entry to wetland areas or to waterways or ditches that
 discharge to larger waterways if the spill occurs on land. If the spill occurs in the
 water, contain or control the spill from spreading and impact shoreline areas or
 larger waterbodies.
- Seal or stop the source of the spill by closing valves, providing containment, or stopping pumps.

3.3 Mitigating, Removing, and Disposing of Spilled Material [112.7(a)(3)(v)]

Only trained personnel with required PPE will perform spill cleanup activities. The Broadwater construction contractor is responsible for cleanup of spills or leaks of materials covered by this plan. Notification procedures should be followed as described in Section 3.5. All spills (including a sheen created on water) must be reported to the Broadwater construction superintendent or, if the construction superintendent is not available, to the Broadwater environmental inspector.

The staging site will have adequate manpower and equipment necessary to divert any spill from reaching waterbodies and wetland areas. Emergency equipment may include, but not be limited to, shovels, backhoes, bulldozers, front-end loaders, oil-absorbent booms, pillows, socks and/or mats, and chemical-absorbent pulp.

Spills onto the ground (soil):

• If possible, stop the source of the spill immediately.

- Berm, divert, or contain the spill.
- Notify the Broadwater construction superintendent or environmental inspector.
- Clean up the spill immediately.
- Apply absorbent material.
- Collect spilled material, and place it into labeled drums.
- Collect absorbent and other material used to clean up the spill, label the container, and properly dispose of waste at an approved disposal facility.
- Decontaminate the affected area, equipment, and surfaces that have contacted the spilled material.

Spills into or that threaten waterways:

- If possible, stop the source of the spill immediately.
- Shut down all equipment and ignition sources in the area.
- Notify the Broadwater construction superintendent or environmental inspector.
- Notify a spill response contractor if necessary.
- Deploy boom and absorbent material to contain the spill.
- Clean up absorbent and waste materials, and dispose of them at an approved waste disposal facility.
- Decontaminate the affected area, equipment, and surfaces that have contacted the spilled material.

3.4 Site Inspections

The Broadwater construction superintendent must conduct daily inspections of the equipment staging and maintenance, fuel staging, hazardous material staging, and hazardous waste storage areas to ensure that spill control measures are in place. Inspections of the project site for general housekeeping and best management practices will be performed weekly.

3.5 Notification and Reporting [112.7(a)(4)]

Notification of an oil discharge or release of a hazardous substance in an amount equal to or greater than the reportable quantity must be made immediately in accordance with 33 CFR 153, Subpart B, and 40 CFR 302, respectively. Notification will be provided to the National Response Center (NRC; 1-800-424-8802) and to the New York State Department of

Environmental Conservation (NYSDEC; 1-800-457-7362). Lists of emergency contacts are provided in Appendix A. The notification process is provided below.

The Broadwater construction superintendent and on-site personnel are responsible for spill prevention, control, and countermeasures. All spills are to be reported to the Broadwater construction superintendent, who will notify the Broadwater environmental inspector. The Broadwater environmental inspector will determine whether state and/or federal notifications are required and will make notification accordingly.

In the event of a minor spill (less than 10 gallons [38 liters] of a known chemical and known source), the construction superintendent shall notify the environmental inspector and complete a written Spill Notification Form (Appendix B). This form describes the time, material, and quantity of chemical released.

If a major spill (more than 10 gallons [38 liters], or an unknown chemical or unknown source) occurs, the environmental inspector will provide written information to the EPA regional administrator, as required by the SPCC plan rules. A copy of this information will be provided to NYSDEC. This will be in addition to the notification procedures described above.

After the appropriate telephone calls are made and the spill is contained, a Spill Notification Form (Appendix B) will be completed for any spill and submitted to the environmental inspector. The Spill Notification Form includes a checklist to document the proper notification of state and federal agencies, if required.

3.6 Training [112.7(f)]

Broadwater will provide training on the SPCC plan to personnel and/or contractors involved with handling petroleum products or hazardous materials. This training will include the contents of this SPCC plan (e.g., spill prevention planning, spill source and receptor recognition, spill prevention and containment techniques, spill response measures, and spill reporting protocol). Broadwater's environmental inspector shall arrange for the training, which will also include the following topics:

- An introduction to pollution control laws and penalties for noncompliance;
- Rules and regulations pertaining to the use and storage of petroleum products;
- Inspection, operation, and maintenance of spill equipment, and petroleum storage and dispensing equipment;
- Spill response and cleanup;
- Spill notification and record keeping; and
- Spill prevention practices.

The Broadwater construction superintendent will maintain records of training attendance and topics.

All personnel are responsible for spill prevention. Any Broadwater employee or contractor who notices a leak should respond as appropriate based on his or her training. If a spill has occurred, the spill area should be isolated and the construction superintendent or environmental inspector should be notified, as required.

3.7 Area Plans

EPA and the United States Coast Guard (USCG) administer area plans for spill contingency response by region throughout the United States. USCG covers coastal areas, and EPA covers inland areas. In a major spill event, contacting the NRC hotline will trigger assistance from the appropriate agency, if necessary. The Broadwater Pipeline is within USCG's area of responsibility for oil and hazardous material releases. The USCG Marine Safety Office Sector Long Island Sound, (MSO), New Haven, Connecticut, acts as the predesignated Federal On-Scene Coordinator for the project location. USCG MSO Sector Long Island Sound may be contacted 24 hours per day at (203) 468-4404.

Appendix A Emergency Contacts [112.7(a)(3)(vi)]

Emergency Contacts

Spill Reporting Hotlines

Agency	Telephone #
New York State Department of Environmental Conservation	
Oil Spill Response	
National Response Center (USCG/EPA)	800-424-8802
United States Coast Guard Marine Safety Office, Sector Long Island	203-436-4404
Sound	

Local Emergency Agencies

Agency	Telephone #
Fire Department (inside city limits)	
Police Department (inside city limits)	
Suffolk County (outside city limits)	

Spill Response Contractors

Company/Location	Telephone #
(To be determined)	

Owner/Operator (Broadwater)

Name/Title	Telephone #
(primary)	
(secondary)	

Construction Contractor

Name/Title	Telephone #
Construction Superintendent (to be determined)	
Environmental Inspector (to be determined)	

See Appendix B for Emergency Response—Spill Notification Form.

Appendix B Spill Notification Form

Spill Notification Form

1. Person Reporting Spill or Incident:	
Name:	Address:
Organization:	
Title:	Telephone:
Signature:	Fax:
2. Type of Spill:	
Common Name of Spilled Substance:	
Quantity Spilled (Estimate):	
Concentration (Estimate):	
Date of Spill:	
Time Spill Started:AMPM	Time Spill Ended: AM PM
3. Location of Spill:	
SPILL TO LAND:	SPILL TO WATERBODY:
Name of site:	Name of waterbody:
Street address:	Location of discharge with reference to fixed point:
City/Town:	Description of area that spilled material may reach:
County:	County:

All spills are to be reported to the Broadwater construction superintendent, who will notifiy the Broadwater environmental inspector. The Broadwater environmental inspector will determine whether state and/or federal notifications are required, and will make notification accordingly.

APPENDIX E WATER QUALITY/SEDIMENT QUALITY MODELING REPORT

E-1 PUBLIC

BROADWATER

WATER QUALITY/SEDIMENTATION MODELING REPORT

FOR A

PROJECT TO CONSTRUCT AND OPERATE A

LIQUEFIED NATURAL GAS RECEIVING TERMINAL

IN

LONG ISLAND SOUND

LONG ISLAND, NEW YORK

United States of America

JANUARY 2006

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List of Acronyms and Abbreviations

ADCP acoustic Doppler current profilers

ASP Analytical Services Protocol

bcf billion cubic feet

bcfd billion cubic feet per day

BOD biological oxygen demand

BOD₅ biological oxygen demand (5-day)

CFR Code of Federal Regulations

CTDEP Connecticut Department of Environmental Protection

CWA Clean Water Act

°C degrees Celsius

°F degrees Fahrenheit

DO dissolved oxygen

EFH Essential fish habitat

EPA (United States) Environmental Protection Agency

FERC Federal Energy Regulatory Commission

FSRU Floating Storage and Regasification Unit

ft/s feet per second

IGTS Iroquois Gas Transmission System

km kilometer

LA Load Allocation

LNG liquefied natural gas

m meter

m/s meters/second

m² square meter

m³ cubic meter

m³/hr cubic meter per hour

mgd million gallons per day

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mg/L milligrams per liter

NOAA National Oceanographic and Atmospheric Administration

NYSDEC New York State Department of Environmental Conservation

NYSDOS New York State Department of State

PAHs polycyclic aromatic hydrocarbons

PCBs polychlorinated biphenyls

ppm parts per million

ppt parts per thousand

SPDES State Pollution Discharge Elimination System

STV shell and tube vaporization

TMDL Total Maximum Daily Load

USACE United States Army Corps of Engineers

USGS United States Geological Survey

WLA Waste Load Allocation

YMS yoke mooring system

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1. INTRODUCTION

Broadwater Energy, a joint venture between TCPL USA LNG, Inc., and Shell Broadwater Holdings LLC, is filing an application with the Federal Energy Regulatory Commission (FERC) seeking all of the necessary authorizations pursuant to the Natural Gas Act to construct and operate a marine liquefied natural gas (LNG) terminal and connecting pipeline for the import, storage, regasification, and transportation of natural gas. The Broadwater LNG Project (the Project) will increase the availability of natural gas to the New York and Connecticut markets through an interconnection with the Iroquois Gas Transmission System (IGTS). The FERC application for the Project requires the submittal of 13 Resource Reports, with each report evaluating Project effects on a particular aspect of the environment.

The proposed Broadwater LNG terminal will be located in Long Island Sound, approximately 9 miles (14.5 kilometers [km]) from the shore of Long Island in New York State waters, as shown on Figure 2-1 of the Resource Report. The LNG terminal facilitates the sea-to-land transfer of natural gas. It will be designed to receive, store, and regasify LNG at an average throughput of 1.0 billion cubic feet per day (bcfd) and will be capable of delivering a peak throughput of 1.25 bcfd. The Project will deliver the regasified LNG to the existing interstate natural gas pipeline system via an interconnection to the IGTS pipeline. Onshore facilities are discussed in the Onshore Resource Reports.

The proposed LNG terminal will consist of an FSRU that is approximately 1,215 feet (370 meters [m]) in length, 200 feet (60 m) in width, and rising approximately 80 feet (25 m) above the water line to the trunk deck. The FSRU's draft is approximately 40 feet (12 m). The freeboard and mean draft of the FSRU will generally not vary throughout operations conditions. This is achieved by ballast control to maintain the FSRU's trim, stability, and draft. The FSRU will be designed with a net storage capacity of approximately 350,000 cubic meters [m³] of LNG (equivalent to 8 billion cubic feet [bcf] of natural gas), with base vaporization capabilities of 1.0 bcfd using a closed-loop shell and tube vaporization (STV) system. The LNG will be delivered to the FSRU in LNG carriers with cargo capacities ranging from approximately 125,000 m³ up to a potential future size of 250,000 m³ at a frequency of two to three carriers per week.

The FSRU will be connected to the send-out pipeline, which rises from the seabed and is supported by a stationary tower structure. In addition to supporting the pipeline, the stationary tower also serves the purpose of securing the FSRU in such a manner to allow it to orient in response to prevailing wind, wave, and current conditions (i.e., weathervane) around the tower. The tower, which is secured to the seabed by four legs, will house the yoke mooring system (YMS), allowing the FSRU to weathervane around the tower. The total area under the

tower structure, which is of open design, will be approximately 13,180 square feet $(1,225 \text{ square meters } [\text{m}^2])$.

A 30-inch-diameter natural gas pipeline will deliver the vaporized natural gas to the existing IGTS pipeline. It will be installed beneath the seafloor from the stationary tower structure to an interconnection location at the existing 24-inch-diameter subsea section of the IGTS pipeline, approximately 22 miles (35 km) west of the proposed FSRU site. To stabilize and protect the operating components, sections of the pipeline will be covered with engineered back-fill material or spoil removed during the lowering operation. Figure 2-1 of the Resource Report presents the proposed pipeline route.

Installation of the proposed Broadwater Project will result in the unavoidable resuspension of some sediments in association with the trenching operations required for the proposed pipeline. Although subsea plowing will be used to install the pipeline, and is the construction methodology preferred by resource agencies, some sediments will be introduced into the water column as the subsea plow excavates the trench. Resuspension of sediments has the potential to affect water quality through increased turbidity and through reintroduction of buried contaminants to the water column. However, based on laboratory analysis of sediment samples collected along the extent of the Project, no elevated levels of contamination were identified. Therefore, the focus of this modeling exercise focused on the potential dispersion of increased suspended sediments within Long Island Sound. Broadwater modeled the fate and transport of suspended sediments to determine the potential for water quality impacts and the potential impacts on marine organisms from sediment and contaminant deposition.

HDR|LMS used the existing MIKE3 model of New York Harbor-Long Island Sound to determine sediment fate and transport and identify potential water quality impacts associated with installation of the proposed pipeline. This report presents a description of the MIKE3 model, the technical approach used to run the model, the development and verification of the model, and the modeling results. The modeling protocols developed for this Project and submitted to resource agencies for review and comment are provided as an Appendix.

2. MODEL DESCRIPTION

The MIKE3 model is a 3-dimensional, time variable, continuous simulation model. The model takes Long Island Sound hydrodynamics into account to determine the fate and transport of sediments and toxics for use in determining potential water quality impacts resulting from Project installation.

The MIKE3 model uses a 75-m by 75-m grid overlying the pipeline trench in close proximity to the pipeline and a larger 225-m by 225-m grid farther from the installation corridor. Figure 1 shows the entire domain of the model and also highlights the project location where the higher resolution grids were located.

To assess the upward mobility of suspended sediments, a total of 10 vertical layers were incorporated into the MIKE3 model, each with a maximum vertical resolution of 2 m, which allowed the sediments to be tracked in three dimensions.

Figure 1A shows the pipeline route and the location of three Acoustic Doppler Current Profilers (ADCP) that were placed along the planned route in the spring of 2005.

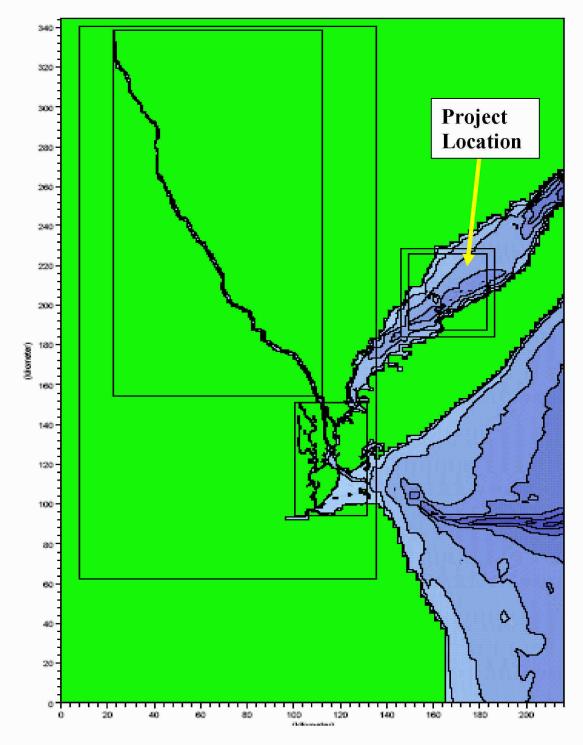


Figure 1. MIKE3 Model Domain and Project Location

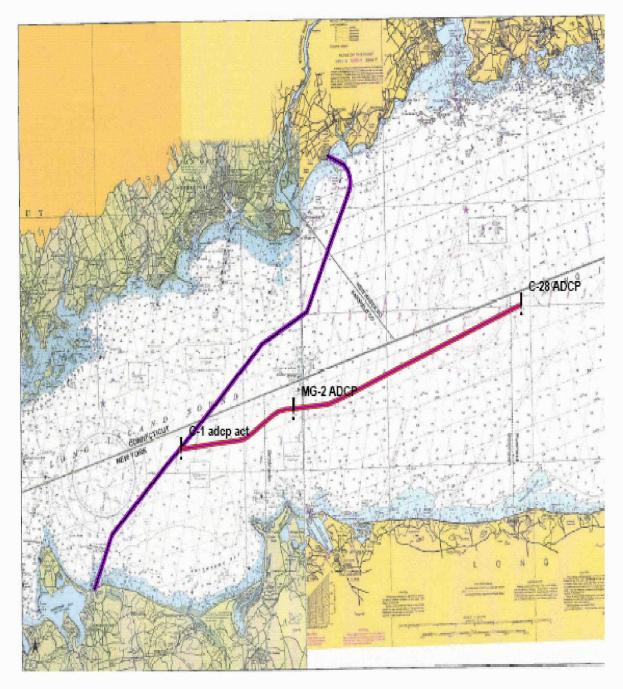


Figure 1A. Pipeline Route and ADCP Locations

2.1 MODEL INPUTS

The anticipated volume of sediments that will be resuspended in the water column as a result of trenching by the subsea plow was input into the model in a time varying manner to simulate the moving plow operation. The anticipated volume and mass of sediment displaced is calculated below. The assumptions used to develop the model inputs are critical to the accuracy of the sediment plume prediction. Where specific inputs needed to be estimated due to lack of data, conservative estimating was followed to ensure that modeling results would present a worst-case scenario.

Where possible, data for the model was obtained directly from the engineering schedule and plan developed for the project. While construction is anticipated to start in October 2009, the actual subsea plowing, which will generate the vast majority of suspended sediment, is scheduled to begin in January of 2010. As such, the model was designed to anticipate the actual conditions that will exist during construction. Plowing of the trench will occur in two successive passes to achieve required depth. Depending on location, the pipeline will be installed to a depth of 3 to 5 feet, requiring a trench that is approximately 7 to 9 feet deep. For modeling purposes, it was assumed that the first pass of the subsea plow would excavate to a depth of approximately 5 feet, disturbing the most fluidized sediments on the upper seafloor. The second pass, to achieve installation depth, would require excavation of an additional 2 to 4 feet, based on location along the pipeline. Since the second pass removes more consolidated material and less total volume, the first pass excavation represents worst-case conditions of sediment release into the water column. Therefore, the need to model the second pass is based entirely on whether sufficient residual sediment remains suspended in the water column between the first and second pass to result in a cumulative impact.

To assess the actual volume of sediment introduced into the water column over a given time period, the rate at which the trenching operation moves was input into the model. The first plow installation pass of the entire line is anticipated to take 20 days. The actual plow time estimated for the first pass is only 8 days, with the remaining days required to install the plow, initiate plowing operations, and stepping over existing buried utility lines. Following completion of the first plow pass, the entire plow set-up will be relocated to the starting point to begin the second pass. The second pass of the plow is anticipated to start 21 days after initiation of the first pass, and it is projected to require a total of only 15 days to complete. Supplemental modeling of the second pass will be required only if significant suspended solids remain in the water column at the initiation point. Otherwise, the results of the first run can be used to do a worst-case assessment of any additional sedimentation generated.

While specific project information needed to be input into the model, the hydrodynamics of Long Island Sound were built into the model when it was created and calibrated to the existing velocity, temperature, and salinity

measurements. These input parameters were reviewed and approved by numerous agencies during the initial calibration of the MIKE3 model. The complete set of input data used to run the model is extensive and includes ocean boundary surface elevations, temperature and salinity, wind speed and direction, air temperature, solar radiation, and local river flows and temperatures. While many of these parameters may show consistency across the Sound, the surface elevation is site specific to locations within the Sound. As such, the model reflects the varied bottom topography, which ranges from approximately 53 feet below sea level near the Stratford Shoal, which is the shallowest portion of the Sound traversed by the Project, to greater than 120 feet below sea level.

To confirm the sufficiency of existing model parameters, Broadwater installed three ADCPs for a complete tidal cycle in May and June 2005 at three distinct locations along the proposed pipeline route.

2.1.1 Sediment Resuspension Volume and Mass Calculation

The volume and mass of sediment displaced by the installation operation, including supporting calculations, are presented below.

- Based on trench cross-section profiles, the average cross-sectional area of the trench created by the first pass of the plow equals 67.5 ft² (6.27 m²). This assumes a 5-foot lift of sediment in the first plow pass. The subsequent plow pass will remove a smaller cross-sectional area regardless of whether the trench is excavated to 7 feet or 9 feet.
- Based on sediment core data (*see the 2005 Environmental Sampling Report*), the average porosity equals 70%, or 0.7 (i.e., while 70% of the sediment is comprised of solid material, the remaining 30% is pore space occupied by water).
- To develop an estimate of the volume of sediment present in a given volume in a standardized trench section 1 meter long, the volume of solids per meter of trench equal $6.27 \text{ m}^2 \text{ x } 1 \text{ m x } (1 0.7) = 1.88 \text{ m}^3$.
- Assuming that 20% of the solid sediments moved during trenching operation is not simply pushed into adjacent spoil piles but remains suspended, the volume resuspended per meter equals 1.88 m³ x 0.2, which equals 0.376 m³. Because plowing will simply push the sediment out of the trench, this is considered a conservative estimate to assess the worst-case scenario.
- Assuming the density of solids equals 2,600 kg/m³, the mass of solids ejected per meter of trenching operations equals 0.376 m³ x 2,600 kg/m³, which equals 977.6 kg.

The rate of plowing operations varies from section to section along the pipeline route based on the anticipated sediments encountered. In mud bottoms, progress is estimated to be as high as 3 miles a day, while in the consolidated deposits near Stratford Shoal, progress will be less than 1 mile a day. As an example, a plow rate of 1 mile per day will equal 1,609 meter/24hrs, which equates to 67 m/hr. Based on these assumptions, therefore, the time for the plow to move 1 meter is equal to 53.7 seconds. Using the previous assumptions with respect to density and porosity, the mass ejection rate for this example equals 977.6 kg/53.7 s, which equals 18.2 kg/s for this particular section of the route. Similar calculations were developed for the entire length of the pipeline to reflect anticipated rates of progress.

Assuming that this mass of material is introduced into the water column on a meter-by-meter basis, the MIKE3 model then simulates the movement of introduced sediment based on the sediment type and anticipated tidal movements of the water column over a period of time.

3 COMPARISON OF MODEL AND ADCP DATA

To verify the accuracy of the MIKE3 model in the study area, computed model velocities were compared to collected current data for magnitude and direction. This comparison and data collection information is presented below.

To measure current velocities within the Project area, three Teledyne RD Instruments Workhorse Sentinel four-beam ADCPs were deployed. Station deployment locations are indicated on Figure 1A. Deployment dates for the beginning of data collection ranged from April 29 to May 2, 2005, for the three ADCP units, and the end date for data collection was June 2, 2005, for all three units. The data were collected as part of a large-scale environmental sampling effort for the project to assess existing geotechnical and environmental conditions in the Project area. Bottom data from the ADCP units were processed for comparison to MIKE3 model results.

To convert ADCP data from magnetic to true directions, magnetic declinations were obtained from the National Geophysical Data center Web site (http://www.ngdc.noaa.gov/seg/geomag/declination.shtml). Variations in declination due to the date and the ADCP location were accounted for to ensure that the data from the two sources were evaluated on identical orientations.

The environmental conditions designed into the MIKE3 model simulated the period of April 25 to May 16, 1995. As stated above, the observed velocities collected as part of Project sampling were collected in the spring of 2005. Based on normal tidal variations, it would be expected that the results would vary slightly between the two sources. For comparative purposes, the times of computed velocities were adjusted to permit plotting these values on the same time scale as the ADCP data. The synthetic times assigned to model results were adjusted to synchronize timing of peak values with the observed directions and peak magnitudes. Since the MIKE3 model grid is oriented at an angle of 30° clockwise relative to true north, all computed directions were correspondingly adjusted.

The appropriateness of using the MIKE3 model simulation for May 1995 to represent hydrodynamic conditions during May 2005 was reviewed. Available National Oceanic and Atmospheric Administration- (NOAA-) observed elevation data for this section of Long Island Sound were surveyed. The only NOAA station in this section of Long Island Sound to have data for these two periods is Eatons Neck at Huntington Bay, New York. A correction factor was provided by NOAA personnel (NOAA 2005) so that the data could be used in this analysis.

Comparative statistics for the two time periods are presented below:

24 April – 28 June 1995 Average: 4.11 ft (MLLW)

Max.: 9.49 ft Min.: -0.88 ft

May 2005 (collected by the Project Team)

Average: 4.33 ft (MLLW)

Max.: 10.18 ft Min.: -0.55 ft

The above statistics show that the two tidal periods are comparable. Based on the similarity of the two data sources, it is appropriate to use the model hydrodynamics run for the 1995 period to represent May 2005 tidal conditions. This allows the existing model design, reviewed and approved by regulatory agencies, to be used as the basis for modeling rather than requiring modifications to the integral design of the model.

Results of doppler data comparisons are portrayed graphically on Figures 2 through 7. Computed and observed directions are similar, but computed magnitudes overestimate observed magnitudes, particularly at stations C1 and MG2. This difference could be due to differences in tidal phase for the periods being compared, or differences in surface elevations at the model boundaries, which are specific for 1995, the year for which the model was originally set up to run. The station with the most consistent computed and observed values is location MG2.

These comparative results are summarized in Table 1. To calculate approximate average flood and ebb values, the graphs were reviewed and the following approximate directional ranges were used to sort the observed and computed data into flood and ebb categories:

	FLOOD	EBB	
<u>Station</u>			
C 1	200°-310°	0°-110°	
C28	200°-320°	0°-120°	
MG2	200°-280°	0°-140°	

This approach yields approximate averages since the above ranges do not precisely define ebb and flood conditions, but it is nevertheless useful for comparative purposes. The results in Table 1 generally appear consistent among the stations. Based on the review of the ADCP tidal data with the computed tidal data incorporated into the MIKE3 model, the MIKE3 data is more conservative, and as such would present a worst-case condition of the distribution of sediment in the Sound across one complete tidal cycle. Therefore, the existing data set for the MIKE3 model was used rather than integrating the field-collected ACDP data.

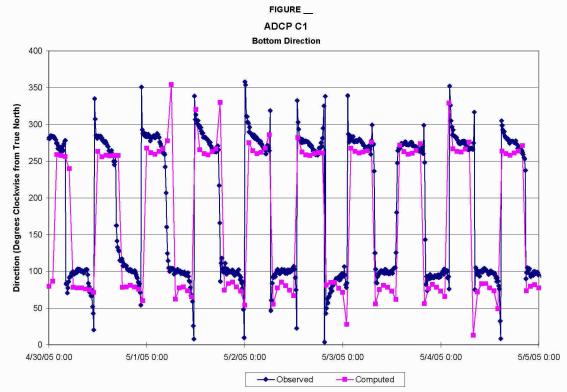


Figure 2. Comparison of Computed and Observed Current Directions for Location C1

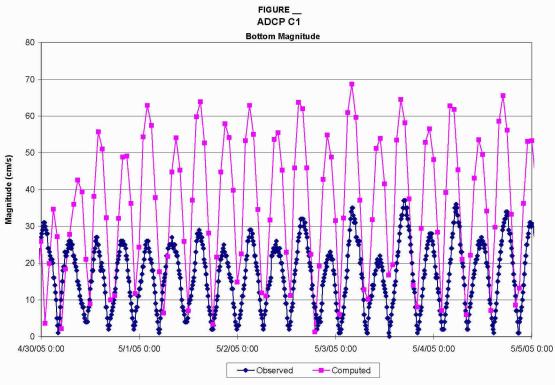


Figure 3. Comparison of Computed and Observed Current Magnitudes for Location C1

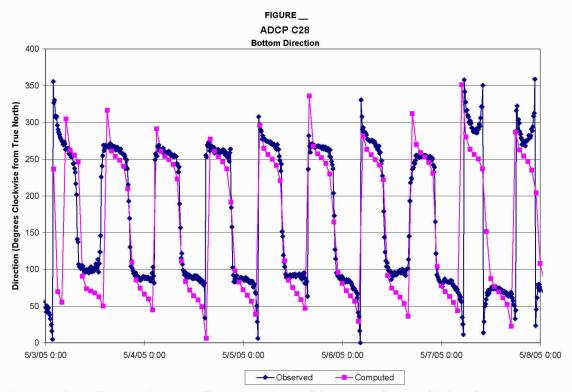


Figure 4. Comparison of Computed and Observed Current Directions for Location C28

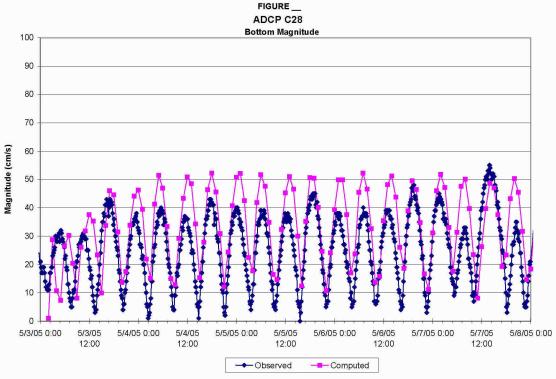


Figure 5. Comparison of Computed and Observed Current Magnitudes for Location C28

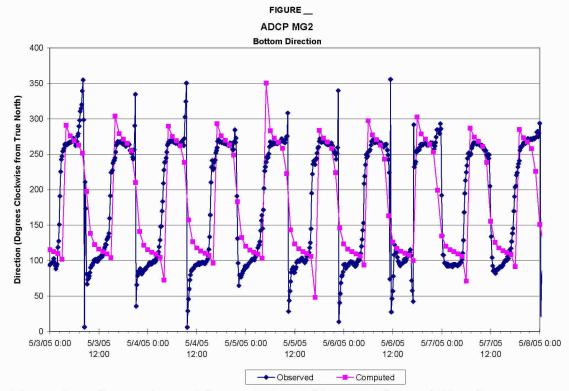


Figure 6. Comparison of Computed and Observed Current Directions for Location MG2

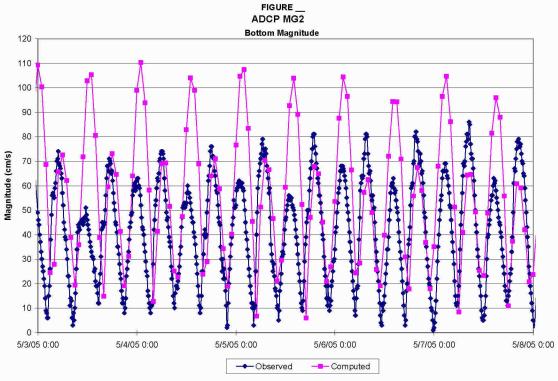


Figure 7. Comparison of Computed and Observed Current Magnitudes for Location MG2

Table 1 Comparison of MIKE3 Hydrodynamic Model Results to ADCP Data

		ent Velocity n/s)	Approximate Mean Current Direction (degrees clockwise from true north)			
			Observed		Computed	
ADCP	Observed	Computed	Flood	Ebb	Flood	Ebb
C1	15.70	33.96	271.6	89.0	264.1	70.0
C28	22.38	32.51	265.8	82.3	255.8	67.3
MG2	35.58	53.43	260.0	90.5	259.3	112.6

4. RESULTS

4.1 CONTINUOUS PLOW OPERATION

The model was devised to run a continuous simulation of the plowing operation. The model run commenced two tidal cycles before the operation began to establish ambient flow conditions. The first pass of the plow operation then commenced and a continuous flux of solids was ejected into the bottom cell of the model that overlays the pipeline route. Since the subsea plow progresses at a minimal speed and the impact is low energy, no sediment is expected to be ejected through the bottom cell into higher cells, except by natural processes reflected in the model. Once ejected to the bottom cell of the model, the suspended solids are then subject to advection and dispersion in three directions by the prevailing tidal currents. In addition, the solids will also naturally settle and deposit back onto the seabed. The tidal fluctuations and the current reverses experienced in the Sound dictate the extent and directional drift of generated sediment plumes. The following sequence of events was established based on the anticipated construction schedule. In essence, this anchors the start time within the specific tidal regime projected to occur during construction. While the times established in the sequence are subject to change, the projected time frames (in days) for specific activities are reflective of the actual time requirements for each item in the sequence of events.

Simulation Sequence of Events

Note: Each timestep reflects one hour.

The modeling run starts January 18, 10 a.m. (time step = 0)

Subsea plowing for first pass starts January 19, 10 a.m. (time step = 24)

Subsea plowing stops January 20, 10 a.m. (time step = 48) for the crossover of the Cross Sound Cable

Subsea plowing resumes January 21, 10 a.m. (time step = 72)

Subsea plowing stops January 22, 10 a.m. (time step = 96) for the crossover of the AT&T Cable

Subsea plowing resumes January 23, 10 p.m. (time step 96 + 36 = 132)

Subsea plow reduces rate of progress January 25, 2 p.m. (time step 132 + 40 = 132 + 40

172) for site-specific conditions across Stratford Shoal

Subsea plowing of shoal begins January 25, 3 p.m. (time step = 173)

Subsea plowing of shoal completed January 27, 2 p.m. (time step = 173 + 47 = 220)

Subsea plowing resumes at higher rate January 27, 3 p.m. (time step = 221)

Subsea plowing of first pass completed January 29, 6 p.m. (time step = 221 + 51 = 272)

End simulation, January 30, 10 a.m. (time step = 272 + 16 = 288)

4.1.1 Start of Plow Operations

The TSS results for the initial 12 hours of the trenching operations are shown on Figures 8 through 28. Figures 8 through 14 show the TSS concentrations on the surface in 2-hour increments from commencement of the operation. The next set of figures (15 through 21) show the same time series at mid-depth. The final set of figures (22 through 28) show the bottom TSS concentrations. As expected, maximum TSS concentrations generated from the plowing operation occur at bottom depths where the sediment is introduced into the water column. This series of maps shows the fate of and distribution of suspended sediments from the plowing activities at a single point along the pipeline. The cumulative impacts from continued plowing operations over an extended time are presented in Section 4.1.2.

T = 0 hrs corresponds to the beginning of the plow operation. The same color scale is used on all the plots in this report and is shown on the right.

The results show only the additional TSS that would be caused by the plow operation and do not include background concentrations that already exist in the Sound. A typical range of Long Island Sound TSS is 20 to 30 mg/L¹, with maximum TSS concentrations that exceed 80 mg/L resulting from natural (e.g., storms) and anthropogenic (e.g., trawling) sources. Field survey and sampling of the Project area conducted in the spring of 2005 yielded TSS results ranging from approximately 10 mg/L to greater than 50 mg/L.

The background TSS levels have not been included in the graphical representation of modeling results due to the minimal increases in sediment observed outside the immediate pipe trench. If background levels were included in the plots, it would be too difficult to distinguish the effect of the plow from the background in most of the plots.

The results demonstrate that the TSS concentrations are greatest at the bottom and decrease toward the surface. This occurs due to the dilution of the plume. Since the Long Island Sound system is tidal, the plume also gets diluted as the currents essentially reverse direction at approximately 12-hour intervals, with current velocities also ranging from near zero at slack and full tides to velocities of as much as 50 cm/sec, depending on location and depth. For this reason, the modeling does not depict an established trailing plume, as would be expected if this operation were to take place in a river, for example. While modeling results depict lower TSS concentrations (typically less than 3 mg/L) being distributed away from the project area, any elevated levels are primarily restricted to the immediate vicinity of the plow. Concentration increases in the surface and middepth range would not be significant enough to create a visible turbidity plume due to the existing TSS levels that normally exist in the Sound.

16 PUBLIC

BW000974

¹ New York City Department of Environmental Protection. 2005. Harbor Survey Data, 1999-2004.

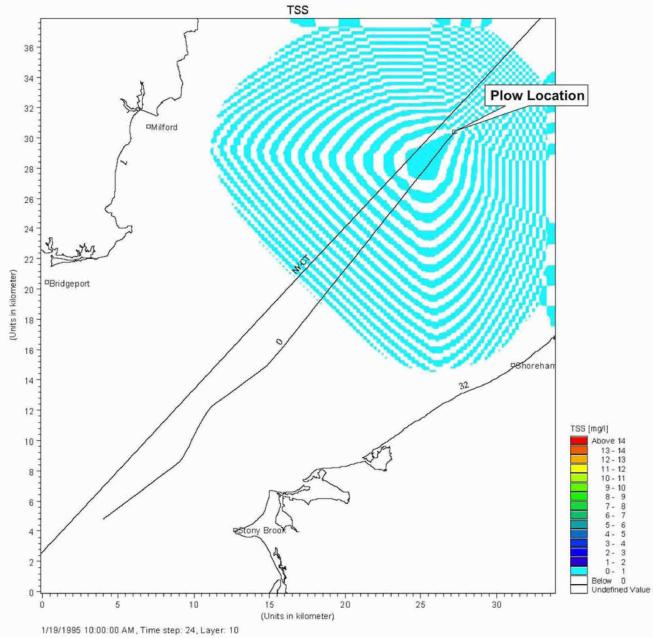


Figure 8. Surface at Timestep = 24 (start of plowing)

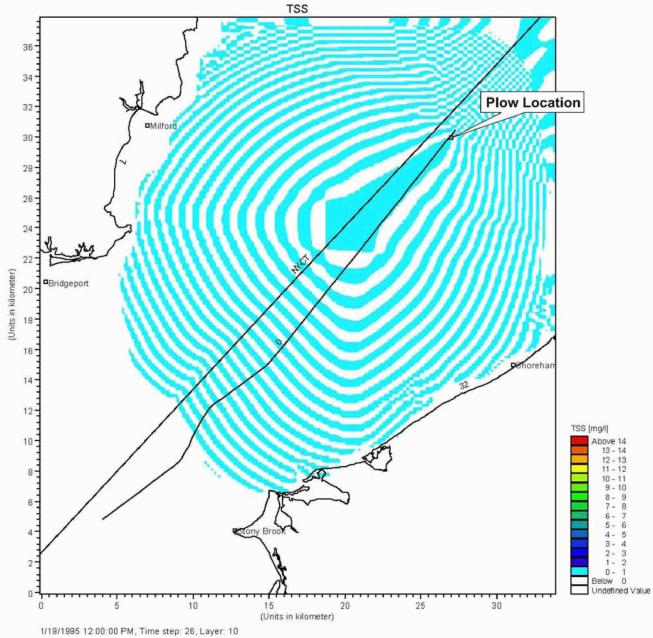


Figure 9. Surface at Timestep = 26 (2 hours after start of plowing)

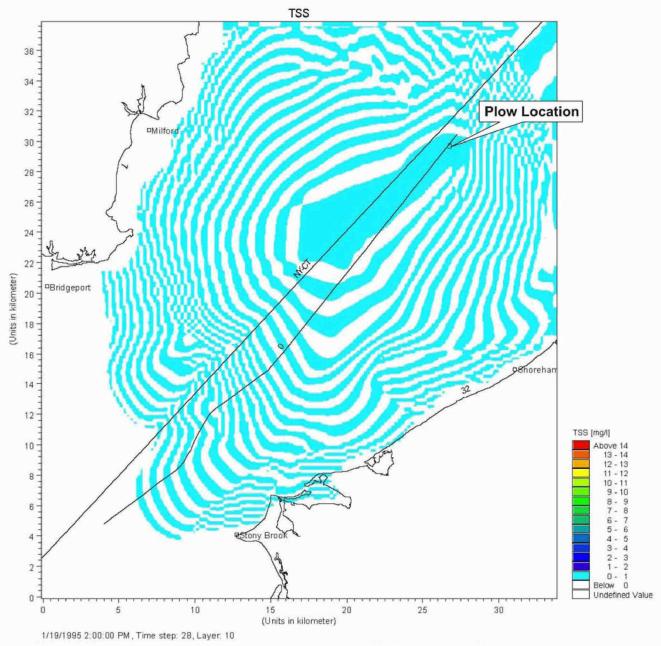


Figure 10. Surface at Timestep = 28 (4 hours after start of plowing)

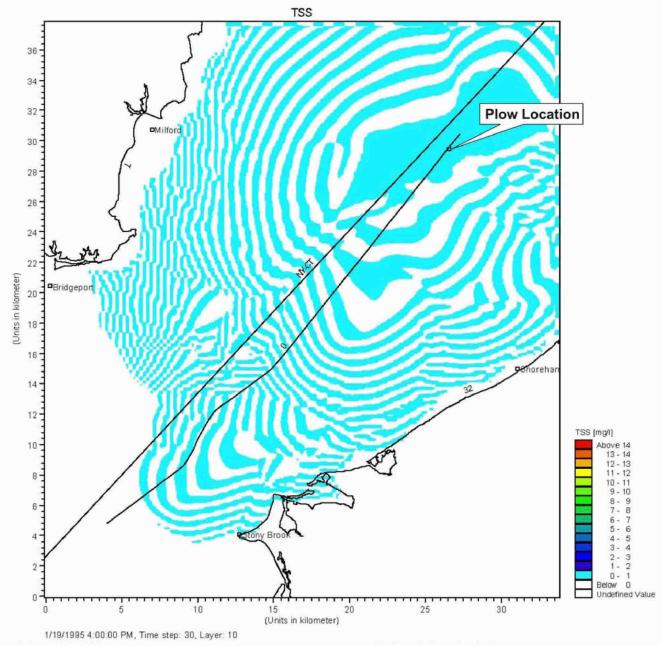


Figure 11. Surface at Timestep = 30 (6 hours after start of plowing)

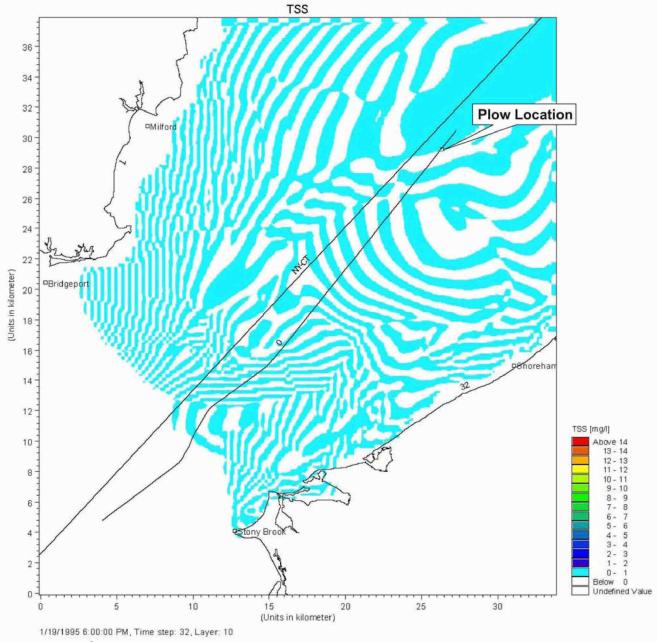


Figure 12. Surface at Timestep = 32 (8 hours after start of plowing)

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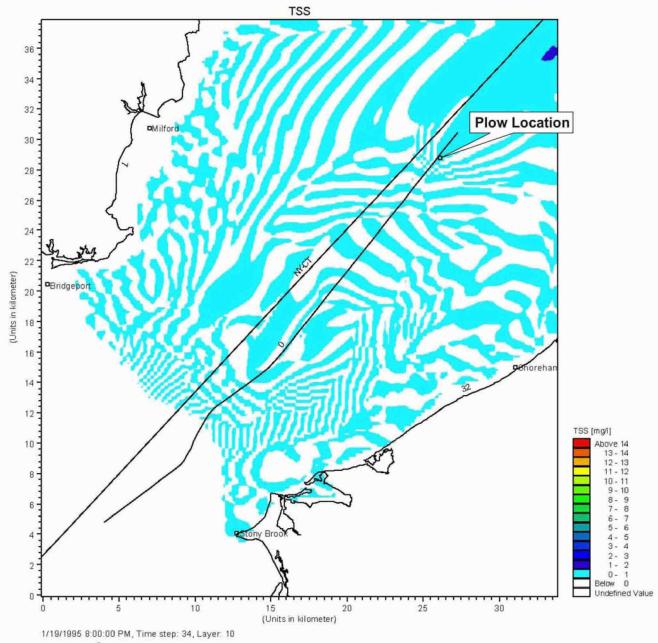


Figure 13. Surface at Timestep = 34 (10 hours after start of plowing)

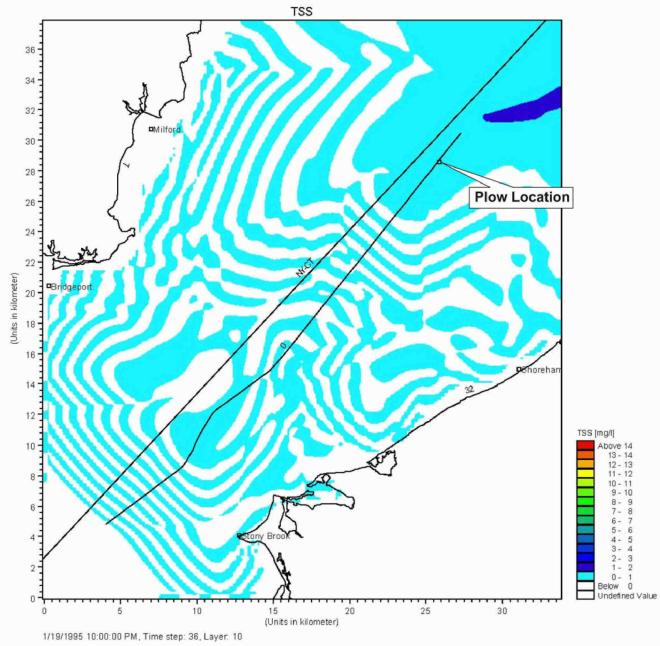


Figure 14. Surface at Timestep = 36 (12 hours after start of plowing)

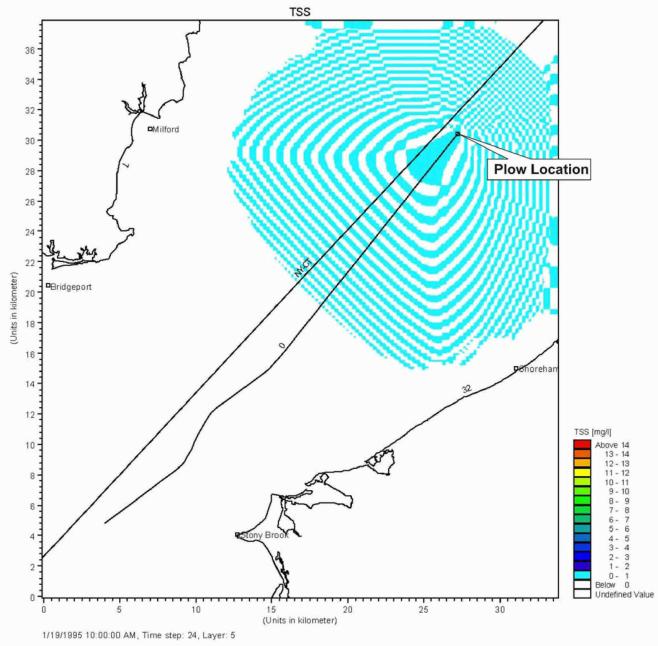


Figure 15. Mid-depth at Timestep = 24 (start of plowing)

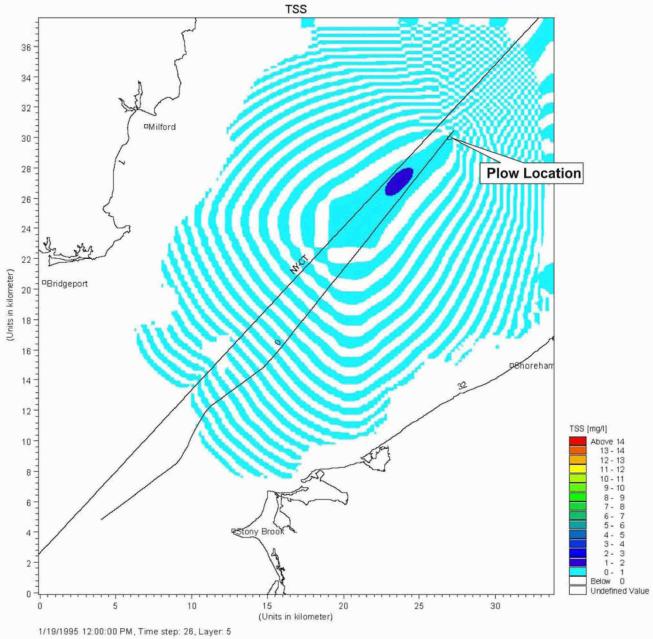


Figure 16. Mid-depth at Timestep = 26 (2 hours after start of plowing)

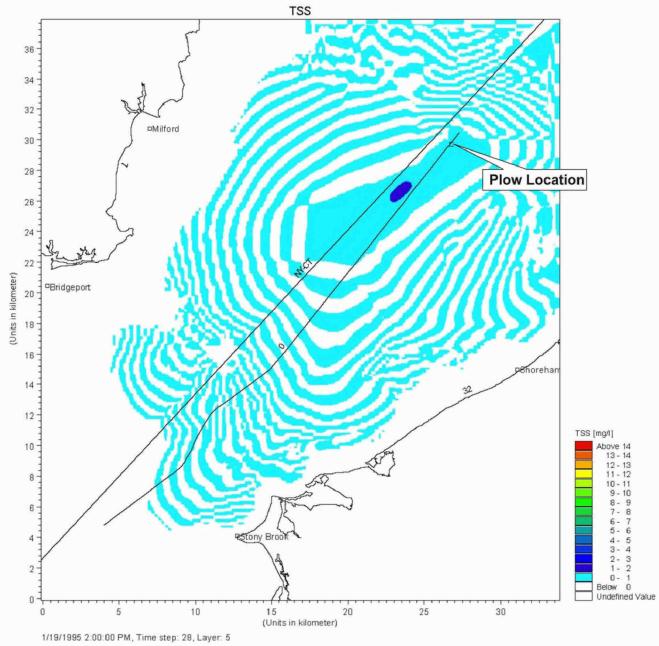


Figure 17. Mid-depth at Timestep = 28 (4 hours after start of plowing)

PUBLIC PUBLIC

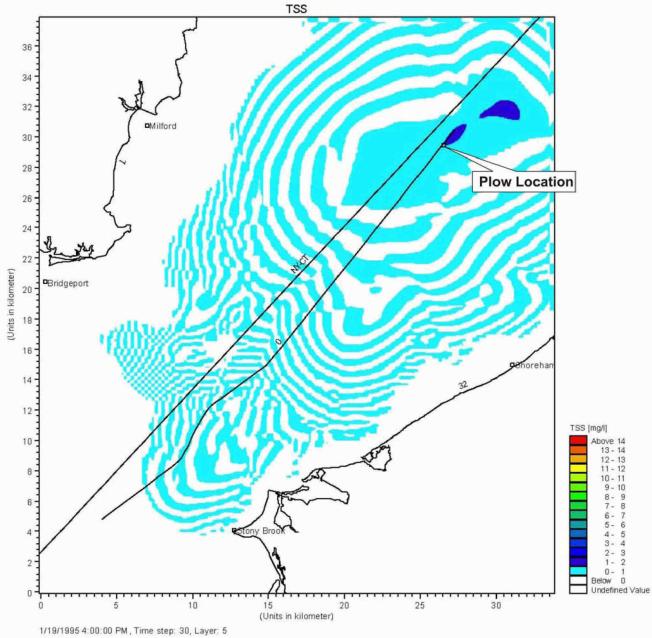


Figure 18. Mid-depth at Timestep = 30 (6 hours after start of plowing)

PUBLIC PUBLIC

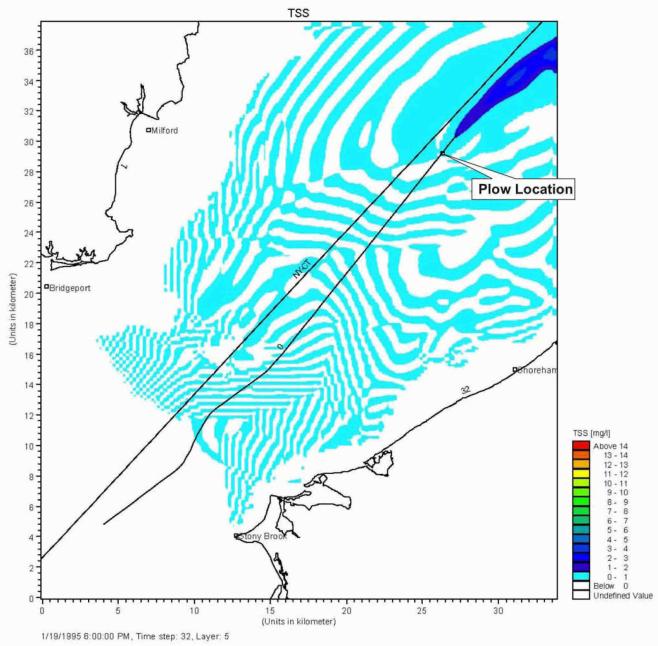


Figure 19. Mid-depth at Timestep = 32 (8 hours after start of plowing)

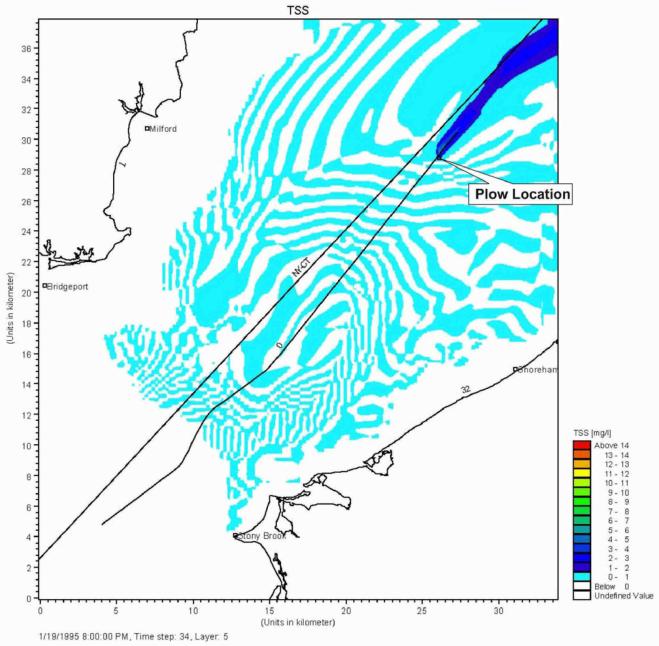


Figure 20. Mid-depth at Timestep = 34 (10 hours after start of plowing)

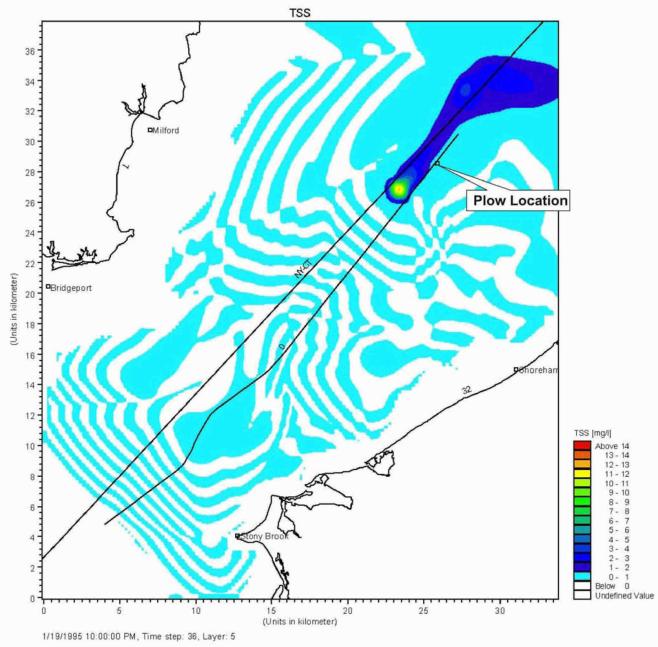


Figure 21. Mid-depth at Timestep = 36 (12 hours after start of plowing)

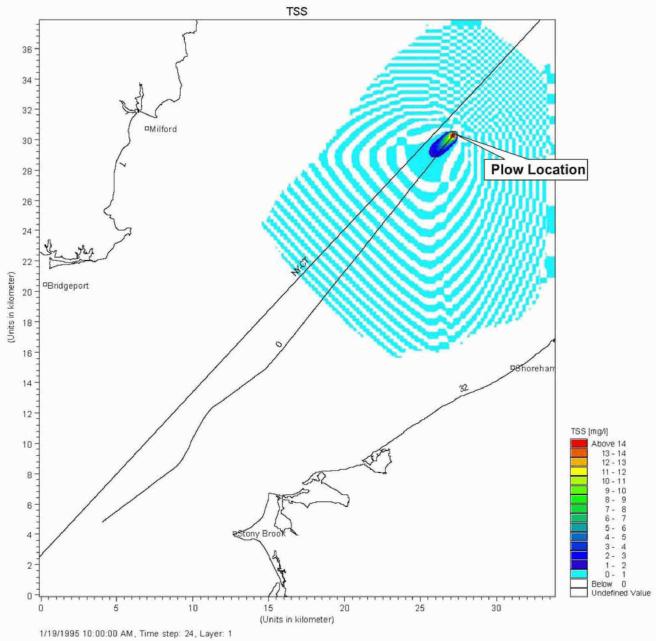


Figure 22. Bottom at Timestep = 24 (start of plowing)

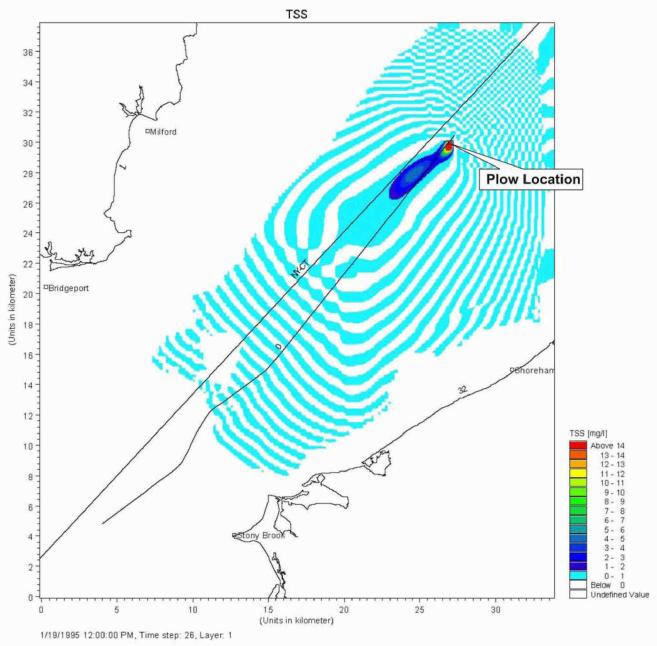


Figure 23. Bottom at Timestep = 26 (2 hours after start of plowing)

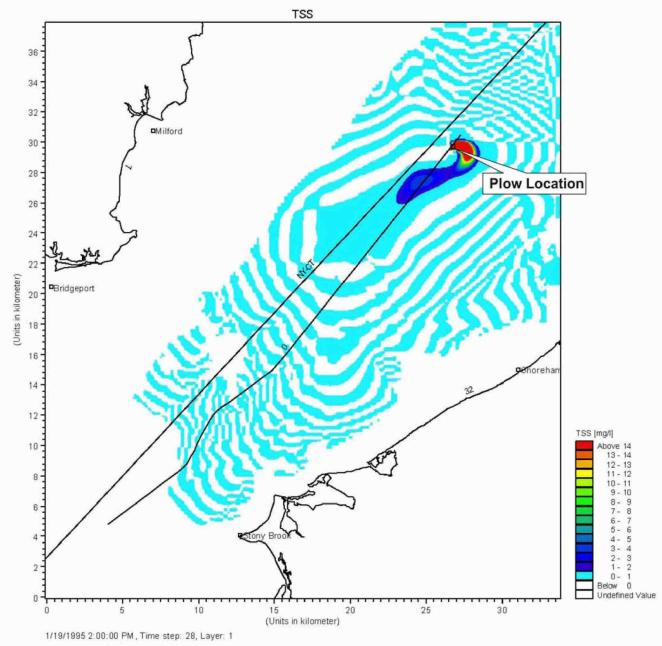


Figure 24. Bottom at Timestep = 28 (4 hours after start of plowing)

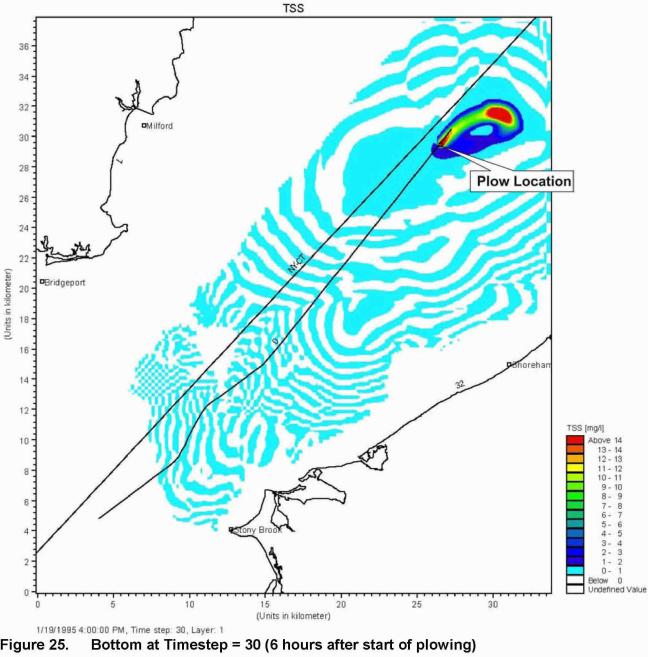


Figure 25.

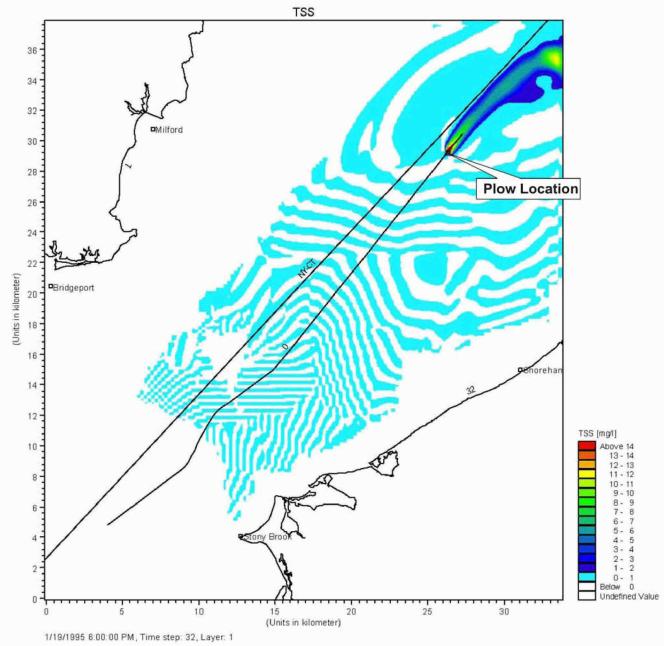


Figure 26. Bottom at Timestep = 32 (8 hours after start of plowing)

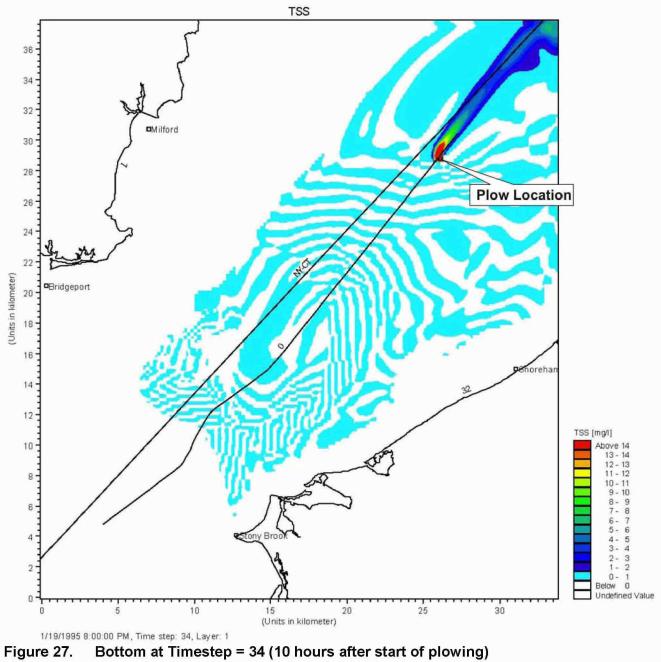
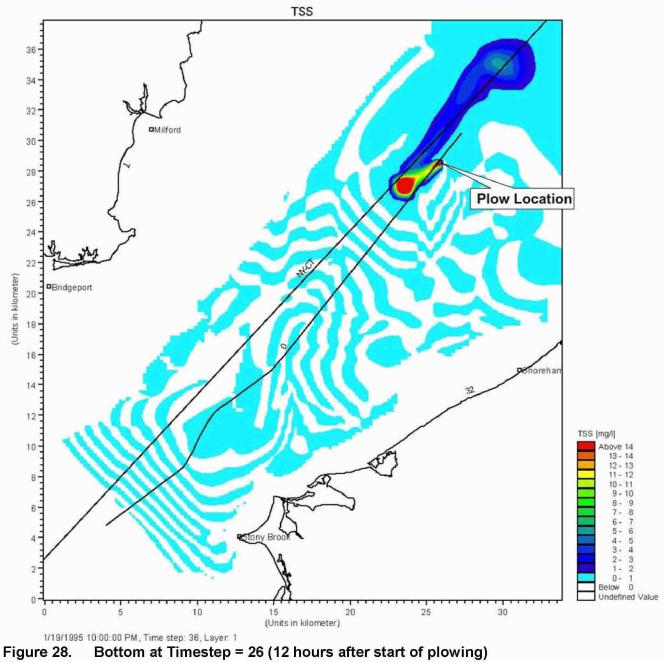


Figure 27.



4.1.2 Ongoing Plow Operations

In order to examine TSS concentrations as the plow continues to trench, a series of plots are shown at 100-hour increments throughout the operation. Rather than assessing the impact at a single point along the pipeline right-of-way, these figures depict the cumulative impacts from ongoing construction activities. Figures 29 through 35 show the surface, Figures 36 through 42 show the middepth, and Figures 43 through 49 show the bottom.

The surface figures show the dual effect of the tidal action and dispersion on the plow operation. The resulting TSS concentrations are largely in the 0 to 3 mg/L range, even immediately above the construction activities, and show no distinct peaks. This minimal increase in TSS would not result in a significant contrast in water color that could be distinguished as a plume. The only notable increase of surface TSS concentrations occur in conjunction with construction at the Stratford Shoal, which is the highest point traversed. While a narrow band of TSS concentrations approaching 10 mg/L over background is evident at the 272 timestep, it has largely dissipated within 12 hours.

At mid-depth the concentrations increase but rarely exceed 5 mg/L. The mapping of the TSS concentrations show a similar trend as seen on the surface, with concentrations slightly higher and more widespread due to proximity to the bottom. Again, these TSS concentrations are not significant in the context of the existing TSS levels in the Sound and would not be visible.

At the bottom the concentrations are higher again, and in the immediate vicinity of the plow can exceed 10 mg/L. As indicated previously, typical TSS levels in Long Island Sound range from 25 to 30 mg/L, although levels can range as high as 80 mg/L or greater. The modeling demonstrates that, in some instances, a concentration of TSS greater than 10mg/L can be transported tidally away from the pipeline corridor. As shown on the figures depicting timesteps 50 through 150 (Figures 29, 30, 31, 36, 37, 38, 43, 44, and 45), a localized concentration of sediment sets up east of the Stratford Shoal, extending into the central portion of the pipeline. The existing longitudinal current trends along the long axis of the Sound, coupled with the increased freshwater inputs from the Connecticut shoreline, restrict the movement of higher TSS concentrations toward more sensitive coastal resources. As shown in the final timesteps, the increased TSS levels are extremely short lived, with levels largely returning to background by the completion of plowing operations. While increased TSS levels of 10 mg/L could potentially be differentiated visually, these levels are restricted to the bottom-most cells of the model and will not be visually evident due the background TSS levels throughout the water column, which largely reduce the clarity of the water. The minimal increase of TSS that results from construction activities falls well within typical TSS levels and is far below the TSS levels that would be associated with higher-energy storm events. The central portion of Long Island Sound where construction will take place is largely identified as a

depositional zone, with annual accretion of the sediment to the bottom from normal coastal processes. The minimal sediment levels experienced during the plowing operations would not result in an appreciable increase of sediment rates beyond the pipeline construction corridor. The use of the subsea plow versus jetting or plowing restricts the soils being introduced into the water column largely to the fine silts that do not readily settle and that will be assimilated into the normal background TSS levels in the water column.

While increased levels of TSS are evident in the immediate vicinity of the plowing operations, the modeling results demonstrate that the TSS levels are quickly reduced to near background conditions as tidal flows in the Sound quickly assimilate the increased sediment loading. Because of the duration of the first plow pass, sediment levels at the initiation point for plowing do not significantly exceed estimated background levels, and would actually be reflective of background levels. Based on these modeling results, cumulative impacts are largely absent due to the time frame of construction activities. As depicted in these series of figures, sedimentation impacts from plow operations have largely insignificant impacts on the overall system.

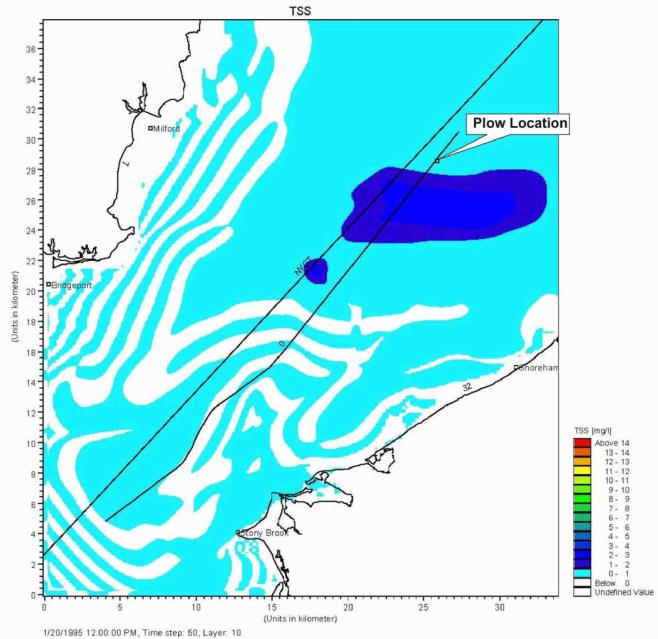


Figure 29. Surface at Timestep = 50

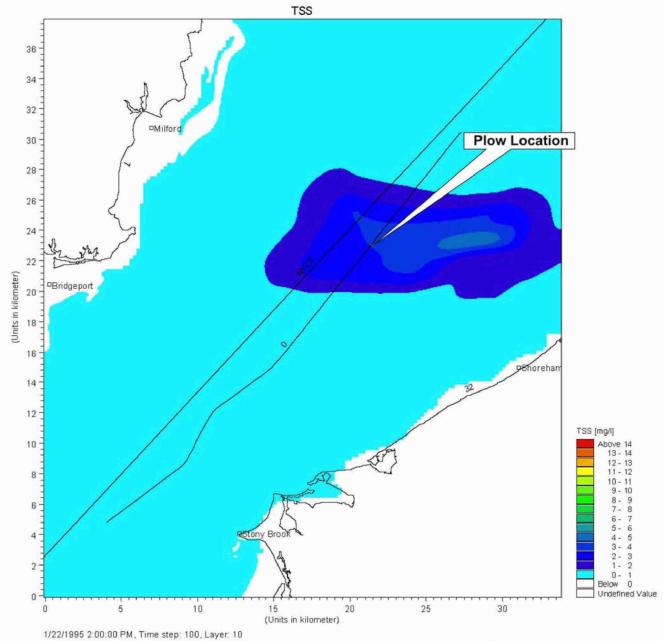


Figure 30. Surface at Timestep = 100

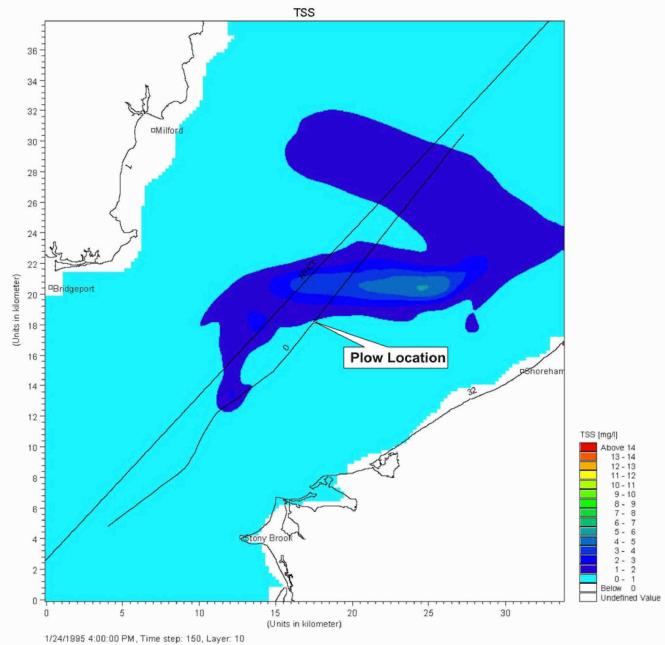
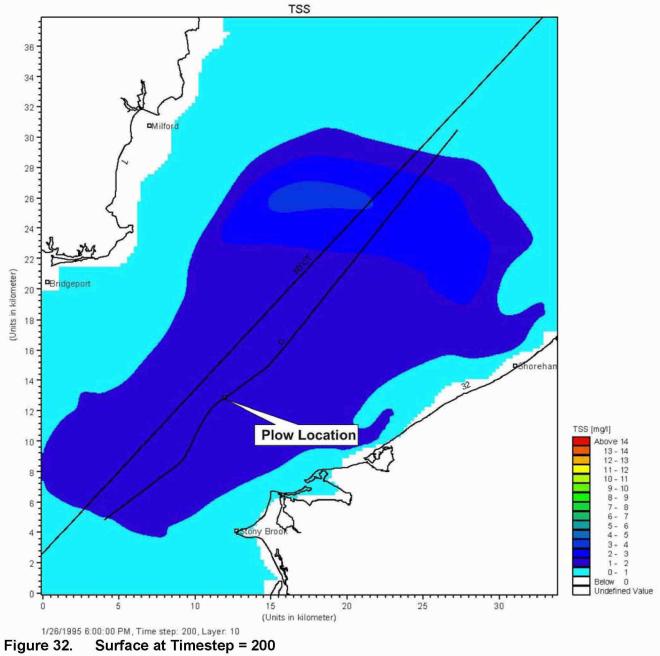


Figure 31. Surface at Timestep = 150



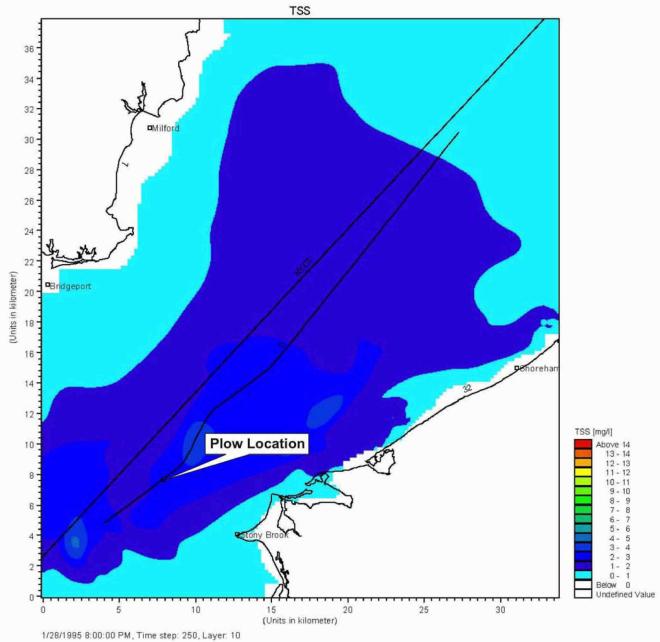


Figure 33. Surface at Timestep = 250

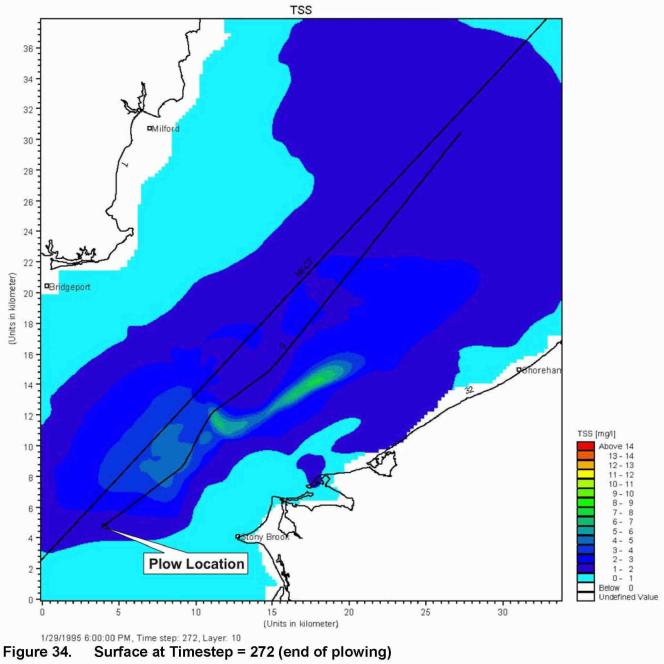


Figure 34.

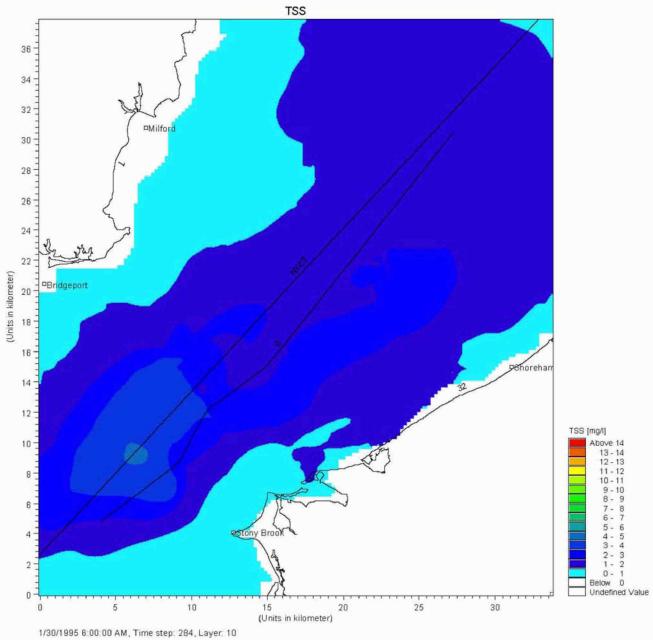


Figure 35. Surface at Timestep = 284 (12 hours after end of plowing)

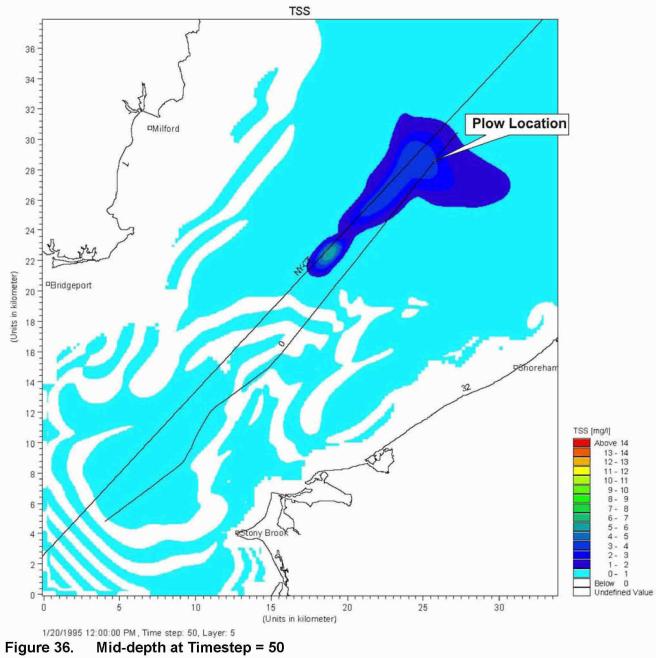


Figure 36.

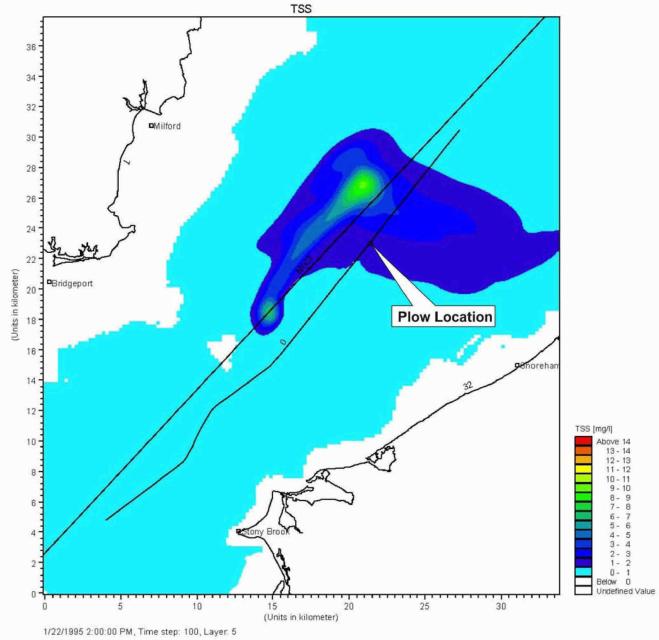


Figure 37. Mid-depth at Timestep = 100

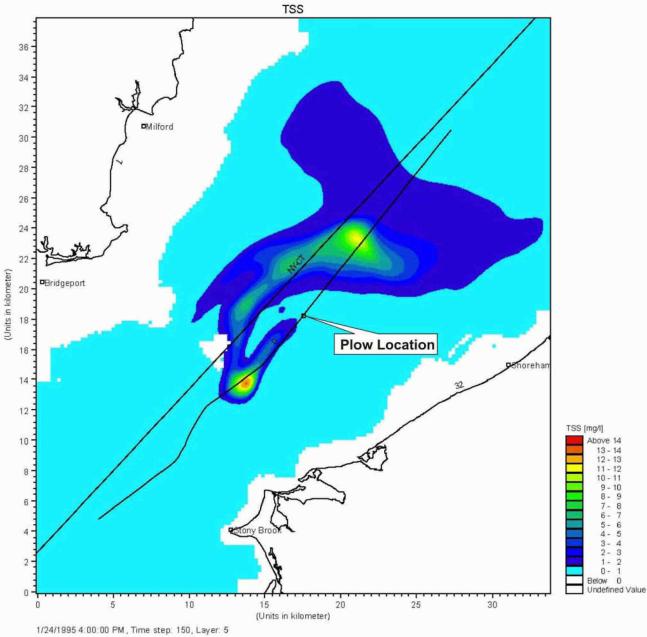
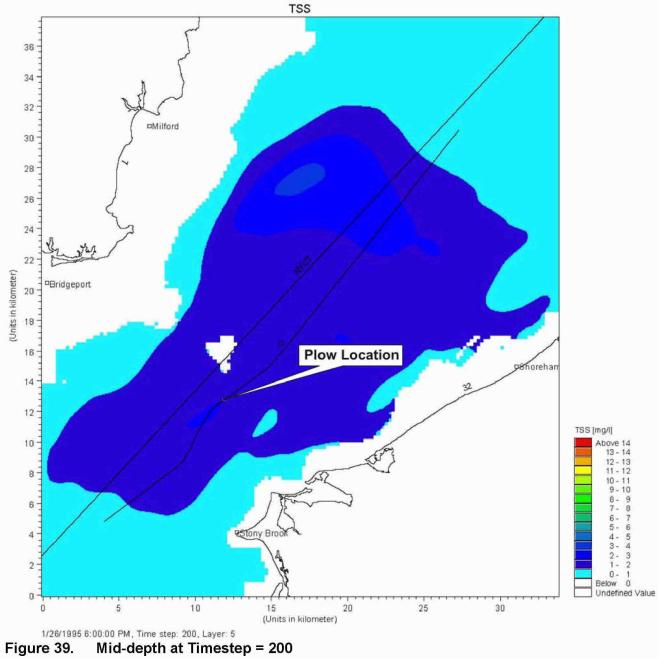
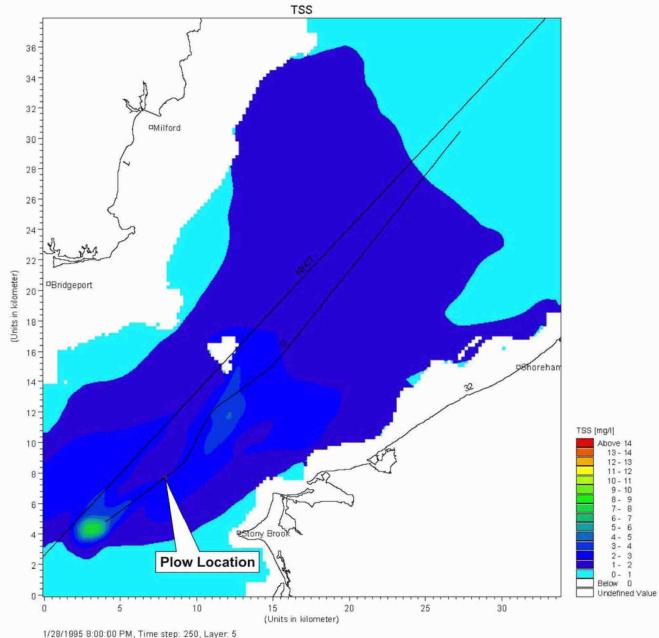


Figure 38. Mid-depth at Timestep = 150





1/28/1995 8:00:00 PM, Time step: 250, Layer; 5
Figure 40. Mid-depth at Timestep = 250

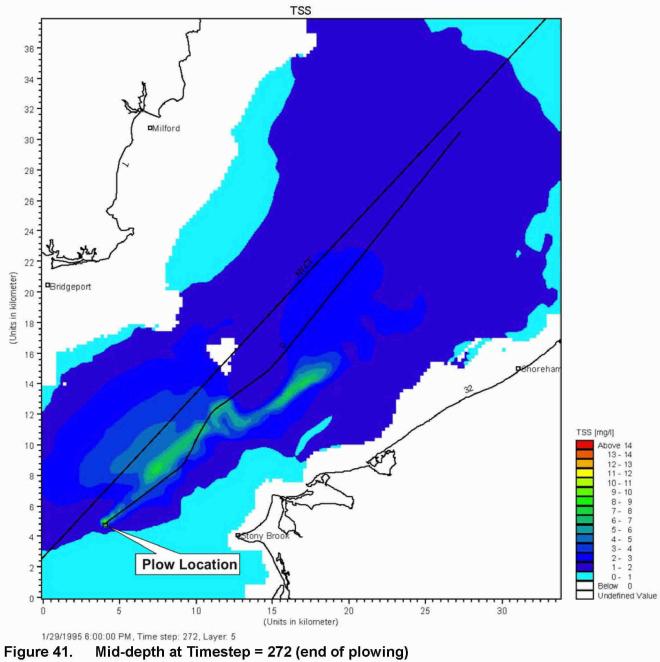


Figure 41.

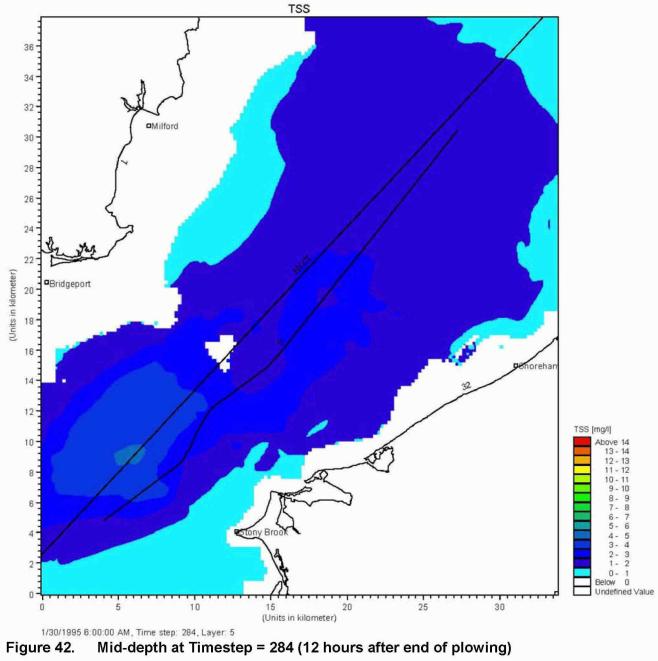
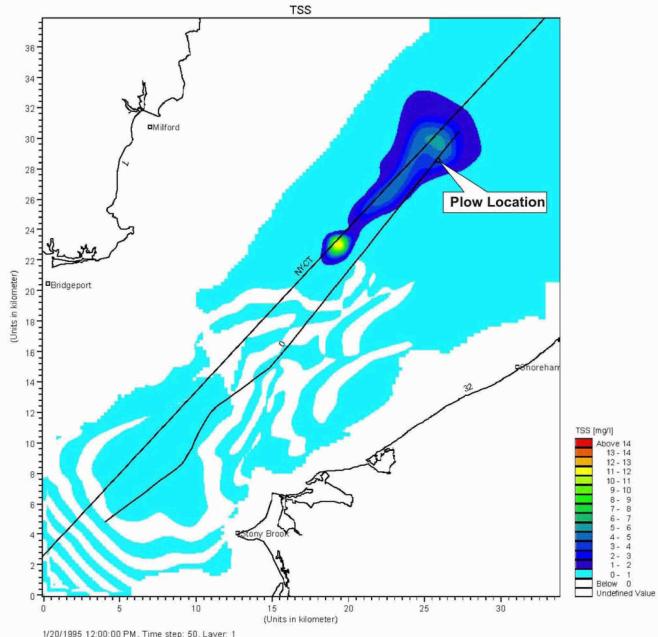


Figure 42.



1/20/1995 12:00:00 PM, Time step: 50, Layer: 1
Figure 43. Bottom at Timestep = 50

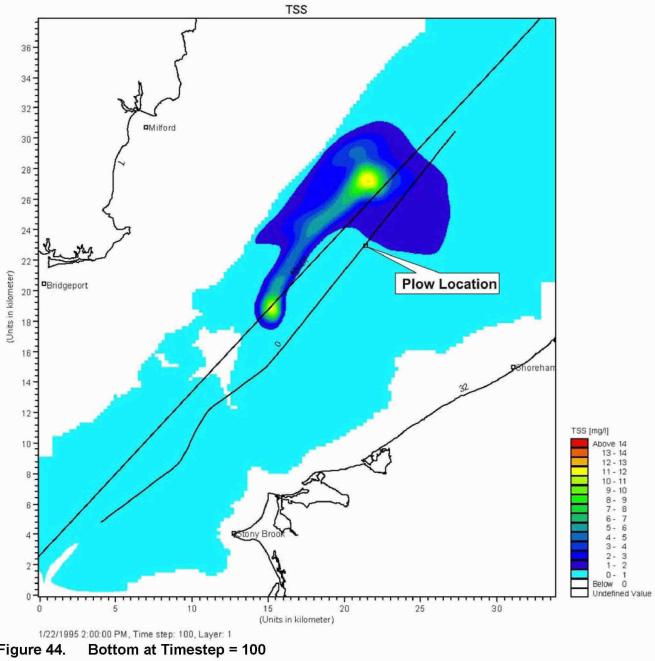
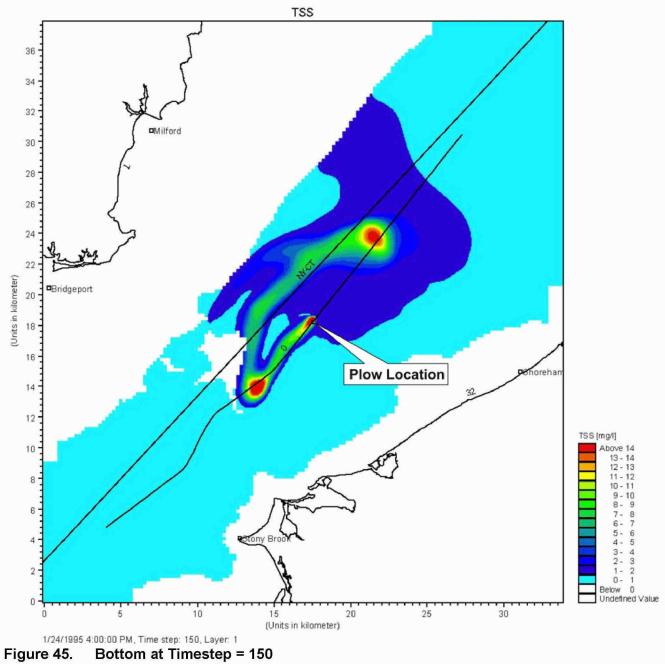
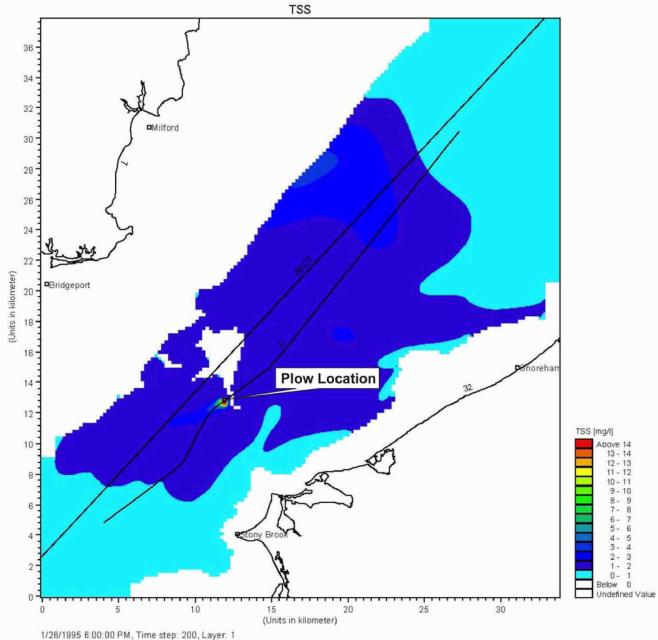
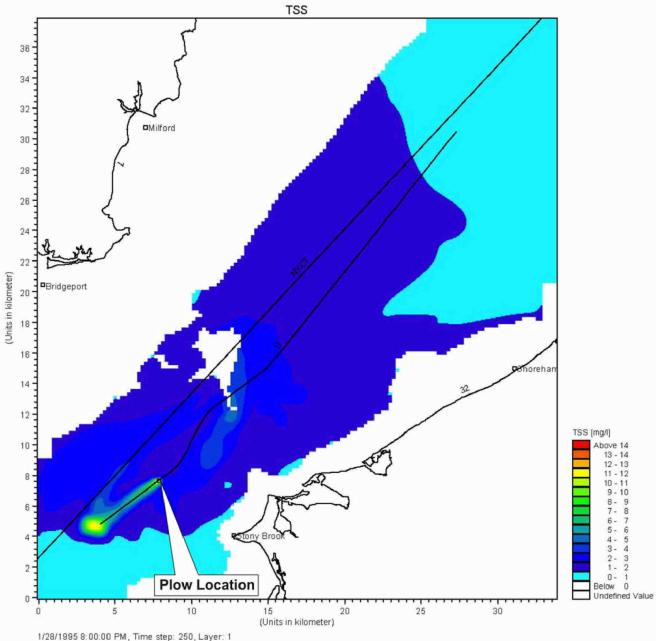


Figure 44.



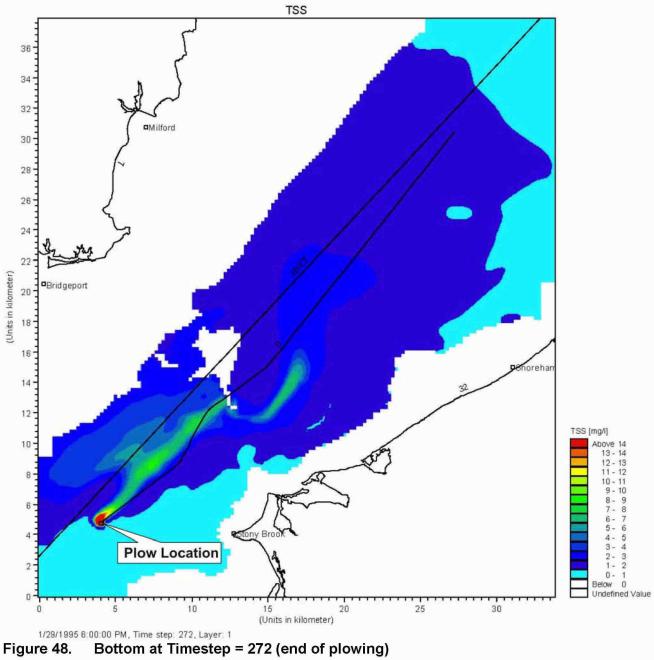


1/26/1995 6:00:00 PM, Time step: 200, Layer: 1
Figure 46. Bottom at Timestep = 200



1/28/1995 8:00:00 PM, Time step: 250, Layer: 1

Figure 47. Bottom at Timestep = 250



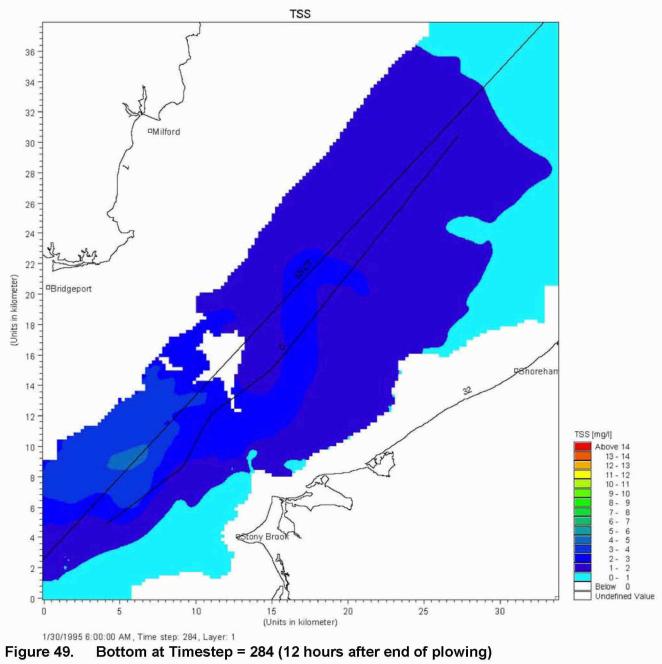
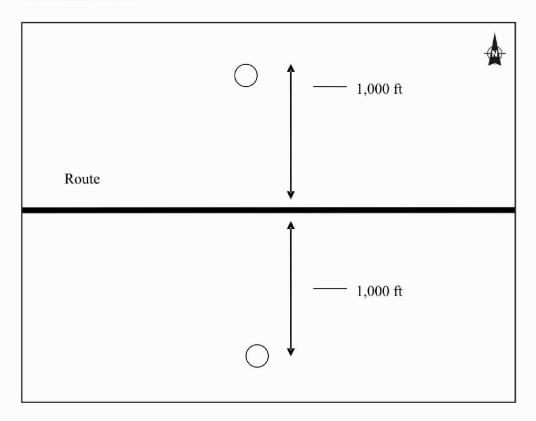


Figure 49.

4.1.3 Response at Points 1,000 Feet from the Trench

While increased TSS concentrations are expected in immediate proximity to the plowing operations, it is not expected that obvious/visible impacts would be evident at a point removed from the trench. To assess the impacts at a specific point removed from the pipeline trench, two arbitrary points 1000 feet south, and 1000 feet north, of the trench route was selected, approximately mid way along the route. The relationship of these points to the pipeline is shown in the schematic below.



A time series of the TSS was then plotted at the surface, mid-depth, and bottom. The results at the point 1,000 feet south of the line are shown on Figures 50, 51, and 52. The results at the point 1,000 feet north of the line are shown on Figures 50a, 51a, and 52a. The plow passed by this point around day 12 of the first plow pass. It is interesting to note that the highest TSS values were actually recorded in the days after the plow had passed by. The cumulative impacts of continued plowing operations were greater than the specific point due to prevailing currents, which took the TSS plume directly over the monitoring point. As shown previously in the time series plots, the TSS concentrations differ significantly north and south of the line. Throughout the period analyzed, TSS levels at the surface ranged from less than 1 mg/L to approximately 4 mg/L above background. Given the daily fluctuation in TSS levels in the Sound, and the variation due to surrounding environmental conditions, the impacts from the increased TSS levels as a result of the construction activities would not be

noticeable. As in the previous plots, the TSS is highest at the bottom and is damped at mid-depth and the surface. While the concentrations at the mid and bottom depths largely remained below 5 mg/L, extremely brief spikes of higher TSS levels were noted, particularly north of the trench. The effect of the tidal period is clear, as the plume is either swept over this point, resulting in the TSS spikes, or the plume moves in the opposite direction, resulting in the low TSS values.

In comparison to the MIKE3 modeling conducted for this project, estimated TSS levels can be compared to the modeling results of previous projects proposed or constructed in the Sound. The Eastchester Project is similar to the Broadwater project in that the pipeline was constructed entirely within New York waters, but parallel to the Connecticut state line.

As part of this filing (see FERC Docket No. CP00-232-000 and -001), Iroquois modeled the potential turbidity resulting from both jetting and dredging. Information presented in the Final EIS for the project indicated that for jetting, modeling predicted a visible turbidity plume (defined as greater than 29 NTU, or 30 mg/L TSS) that would be 7,800 feet in length and 1,900 feet in width. For mechanical dredging, the plume would be approximately 2,600 feet long and 1,300 feet wide. Both of these predictions are far in excess of the anticipated TSS loading associated with subsea plowing. Unlike Broadwater, which used the MIKE3 model, modeling for the Eastchester Project used the COREMIX1 and DREDGE models.

The lack of elevated TSS loading resulting from subsea plowing also largely restricts the potential for excessive sedimentation outside of the approximate 300-foot project corridor.

Point 1000 ft South of Trench - Surface

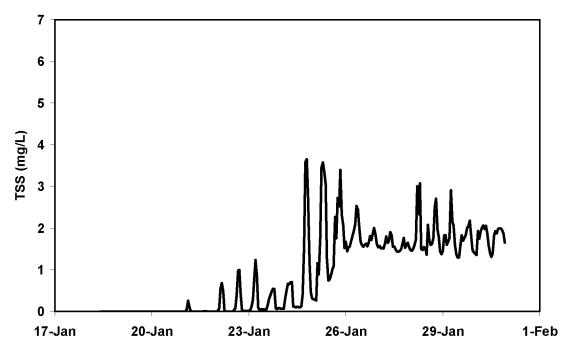


Figure 50. Surface - Point 1,000 Feet South of Trench

Point 1000 ft North of Trench - Surface

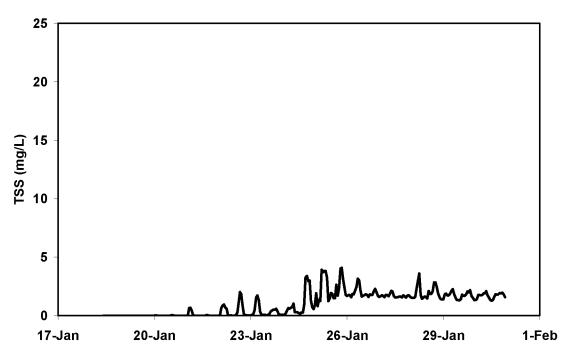


Figure 50A. Surface - Point 1000 ft North of Trench

Point 1000 ft South of Trench - Mid Depth

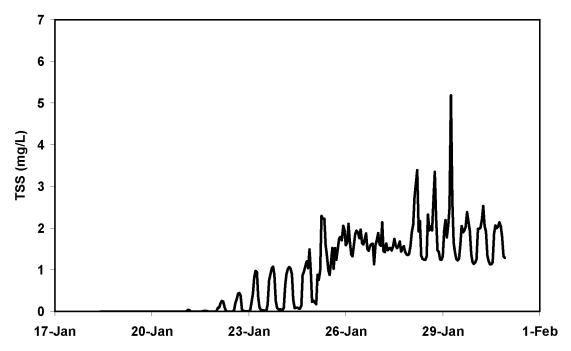


Figure 51. Mid-depth - Point 1,000 Feet South of Trench

Point 1000 ft North of Trench - Mid Depth

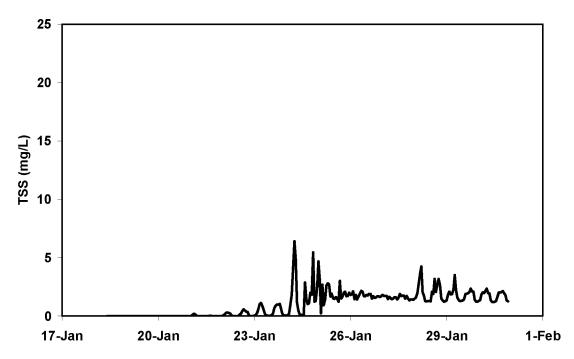


Figure 51A. Mid-depth - Point 1,000 Feet North of Trench

Point 1000 ft South of Trench- Bottom

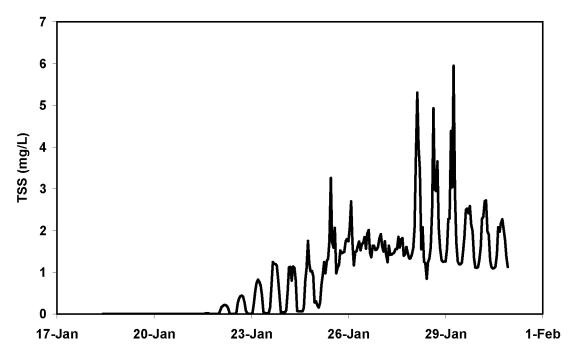


Figure 52. Bottom - Point 1,000 Feet South of Trench

Point 1000 ft North of Trench- Bottom

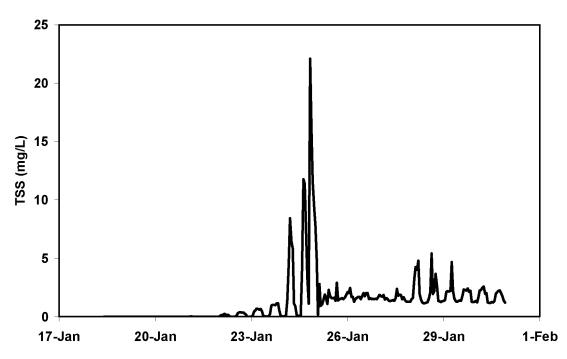


Figure 52A. Bottom - Point 1,000 Feet North of Trench

On top of Route

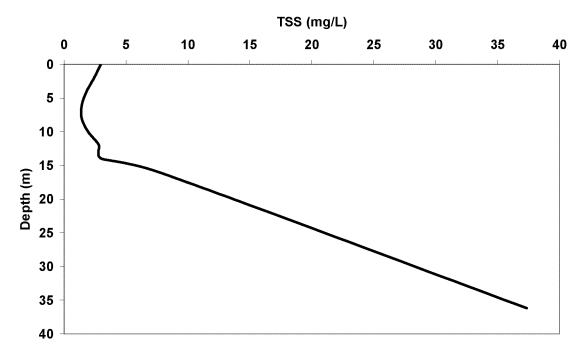


Figure 53. Top of Route

250ft from Route - South

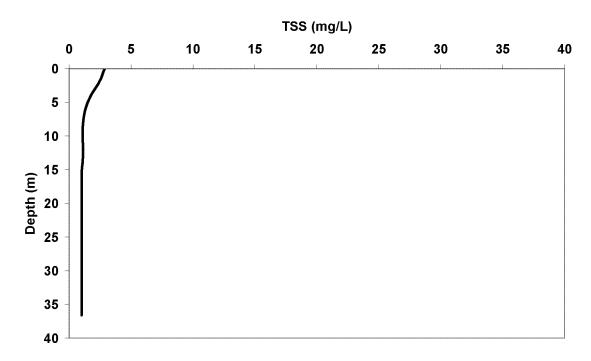


Figure 54. 250 Feet from Route - South

250ft from Route - North

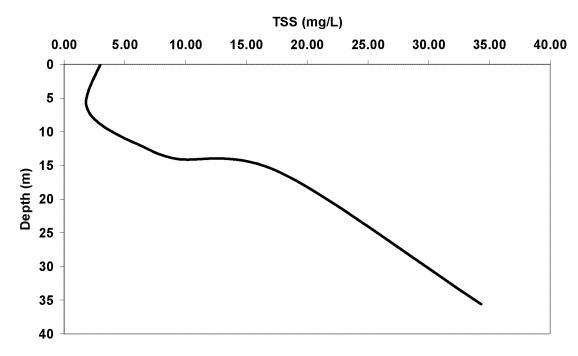


Figure 54A. 250 Feet from Route - North

500ft from Route - South

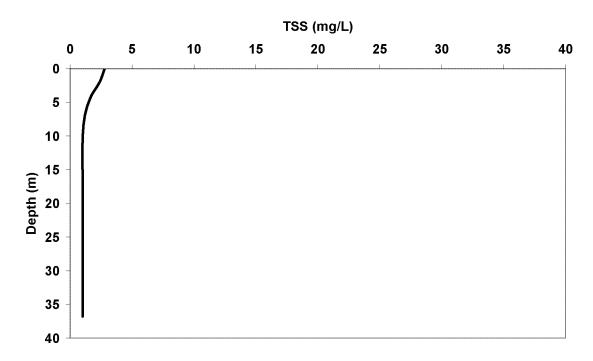


Figure 55. 500 Feet from Route - South

500ft from Route - North

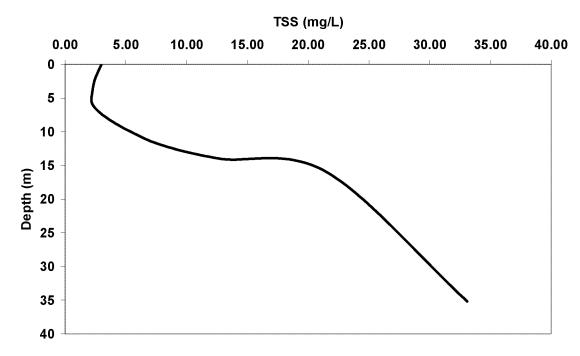


Figure 55A. 500 Feet from Route - North

750ft from Route - South

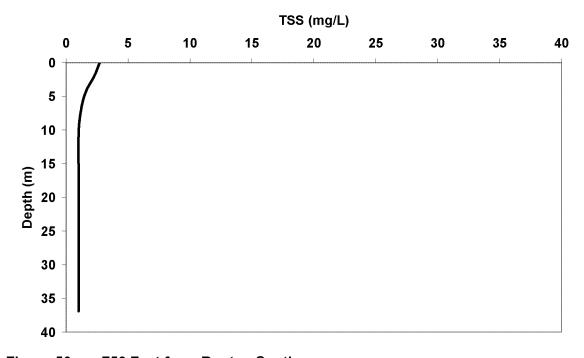


Figure 56. 750 Feet from Route - South

750ft from Route - North

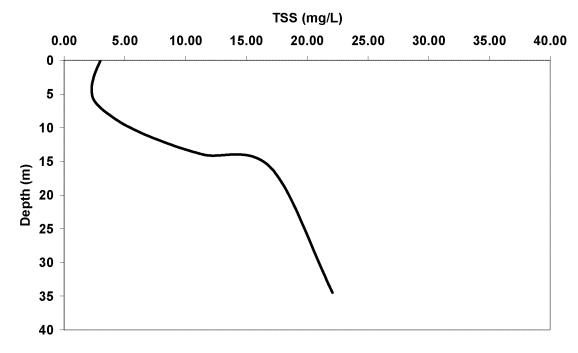
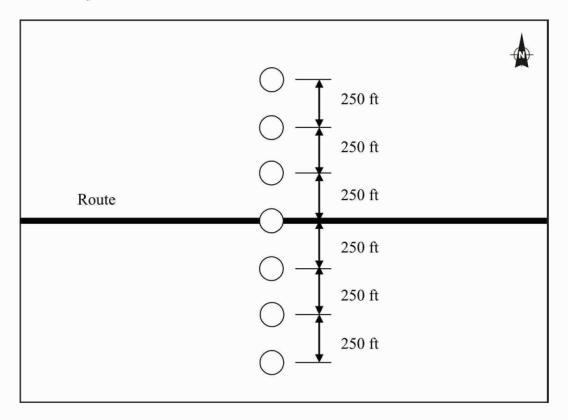


Figure 56A. 750 Feet from Route - North

4.1.4 Vertical TSS Profiles

To show the vertical variation of TSS, a series of plots are shown at the same point along the route as used previously. At this location, the water depth is approximately 75 feet. The vertical TSS profiles were plotted at this point (see Figure 53), then at distances of 250-foot increments away from this point, perpendicular to the route, as shown in the schematic below (see Figures 54, 55, and 56).



The results show how the strong vertical gradients in TSS that are present in the water column over the plow operation are damped with distance with each successive increment. Based on these results, a visible plume would only be evident, at depth, and only immediately on top of the construction activity.

4.2 AIRLIFT OPERATION

4.2.1 Airlift Operation Simulations

Where the pipeline route crosses existing utility lines, it is not possible to use a subsea plow. In these cases hydraulic dredging, also known as airlifting, is utilized. There are two utility crossings along the route. One is the Cross Sound Cable and another is the AT&T cable corridor. The locations of these are shown on Figure 57. As the volume dredged for both cable crossings is the same, only the Cross Sound Cable crossing was simulated. Similar results would be expected for the AT&T crossing.

Hydraulic dredging is also required for the tie-in to the existing Iroquois Gas Transmission System (IGTS) and at the proposed tie-in at the FSRU. These two locations had similar volumes of material to be dredged and only the IGTS location was simulated.

As there is considerable time between each of the hydraulic dredging operations, and with the larger subsea plow operations, it is not expected that there will be any cumulative effects, and hence each simulation contains only one dredging operation at a time. To model the worst-case scenario, it was assumed that the hydraulic dredge would release material at mid-depth, and so the release point in the model is at mid-depth in the water column, in the cells overlying the cable crossing and tie-in locations.

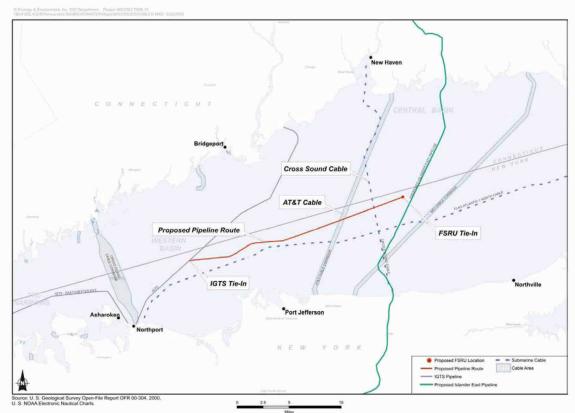


Figure 57. Proposed FSRU Location and Pipeline Route, Existing Pipeline and Cable Routes, and Tie-in Locations

Cross Sound Cable Crossing

The volume of dredged material for the utility crossings is approximately 3,030 yd³, and the operation is continuous over a 3-day period. The pump flow rate is estimated at 1,000 gpm. The model was run for 24 hours before the commencement of dredging. The results for the surface, mid-depth, and bottom are shown on Figures 58 through 78.

IGTS Tie-in Location

The volume of dredged material is 2,340 yd³, and the operation is continuous over a 3-day period. The pump flow rate is 1000 gpm. The model was run for 24 hours before the commencement of dredging. The results for the surface, middepth and bottom are shown on Figures 79-93.

In both modeling runs, increased TSS concentrations were minimal, and extremely isolated to the mid-depth. No increased levels were evident either at the surface or at the bottom.

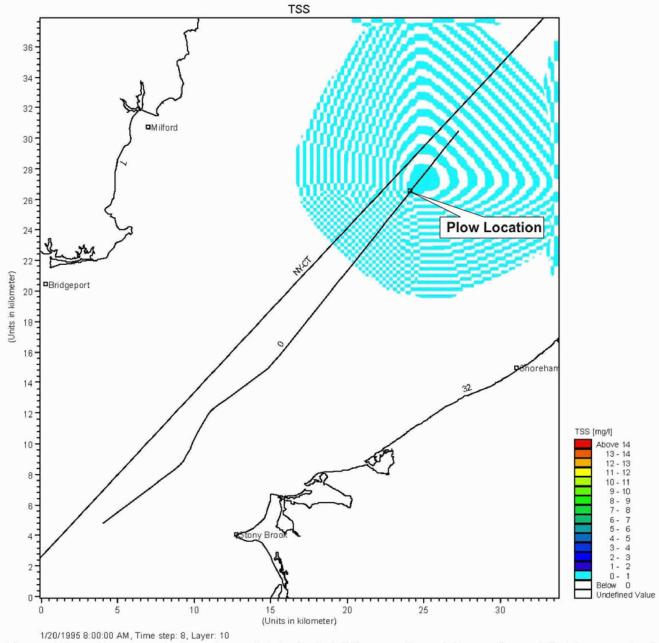


Figure 58. Surface at Timestep = 8 (start of airlift operation at Cross Sound Cable crossing)

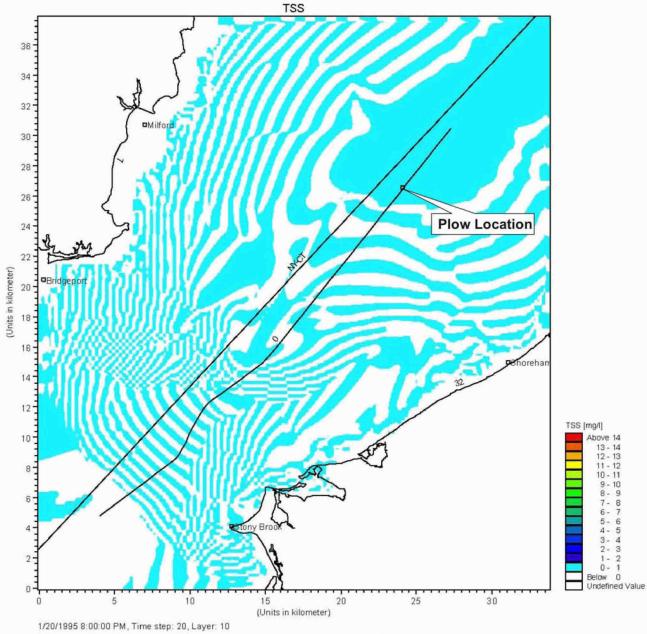


Figure 59. Surface at Timestep = 20 (12 hours into airlift operation at Cross Sound Cable crossing)

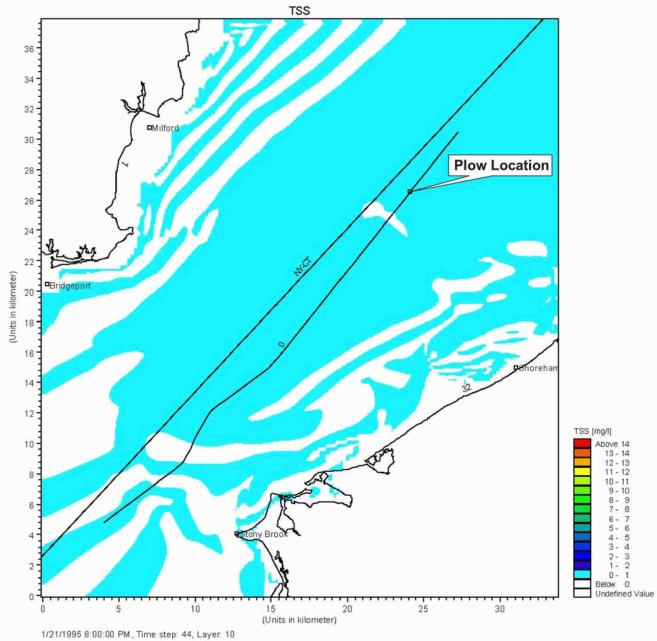


Figure 60. Surface at Timestep = 44 (36 hours into airlift operation at Cross Sound Cable crossing)

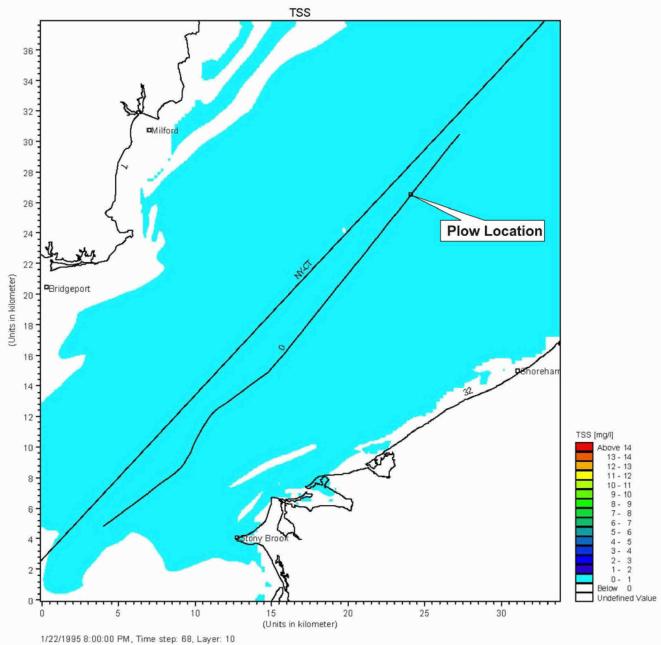


Figure 61. Surface at Timestep = 68 (60 hours into airlift operation at Cross Sound Cable crossing)

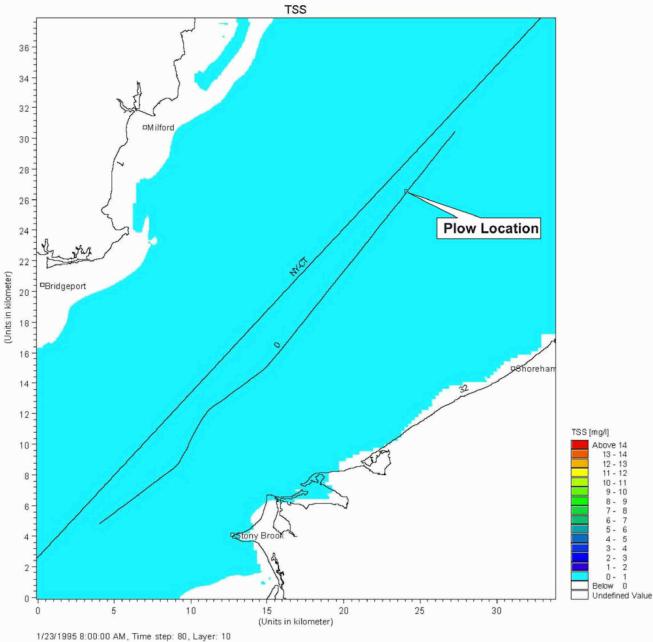


Figure 62. Surface at Timestep = 80 (end of airlift operation at Cross Sound Cable crossing)

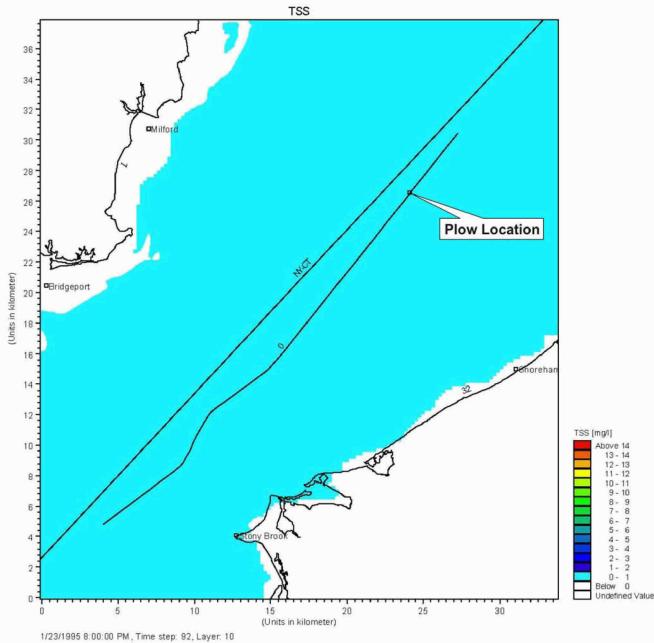


Figure 63. Surface at Timestep = 92 (12 hours after end of airlift operation)

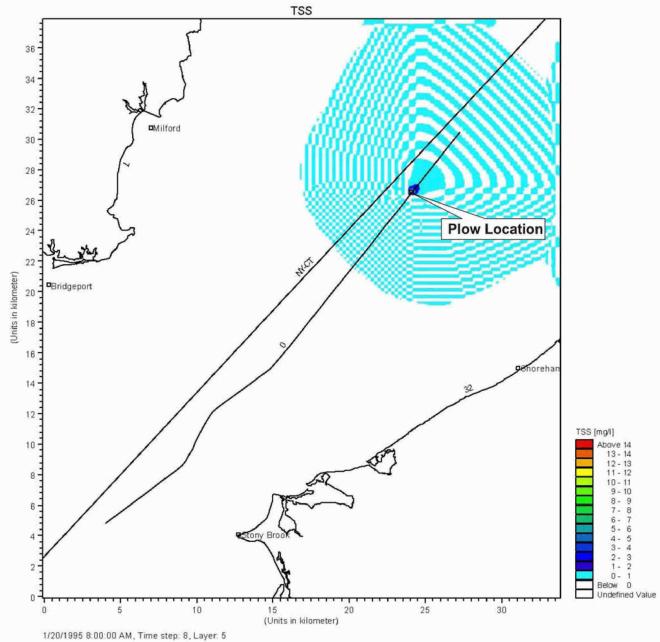


Figure 64. Mid-depth at Timestep = 8 (start of airlift operation at Cross Sound Cable crossing)

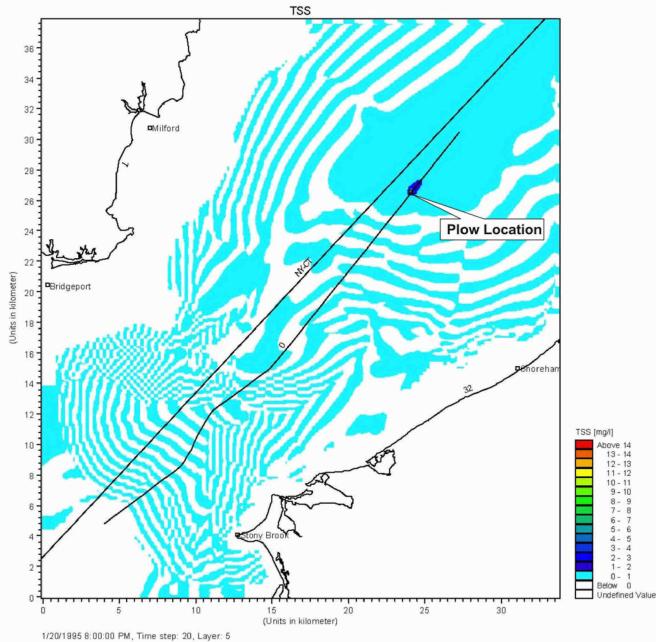


Figure 65. Mid-depth at Timestep = 20 (12 hours into airlift operation at Cross Sound Cable crossing)

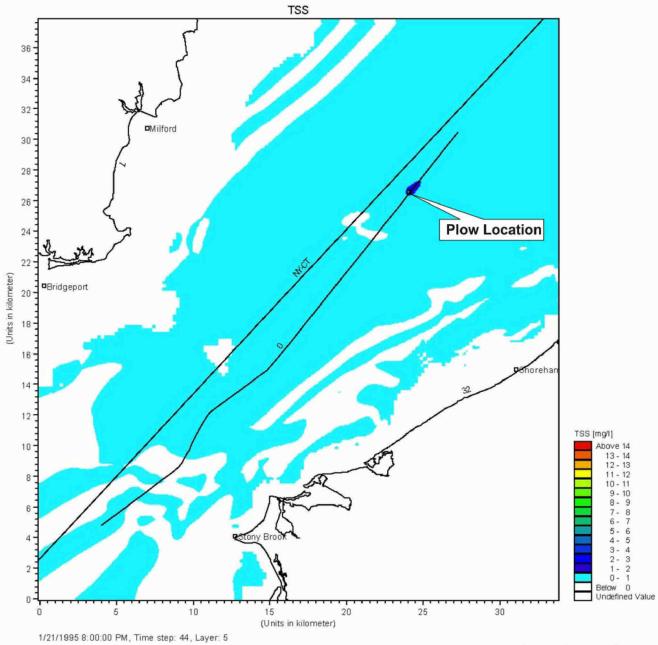


Figure 66. Mid-depth at Timestep = 44 (36 hours into airlift operation at Cross Sound Cable crossing)

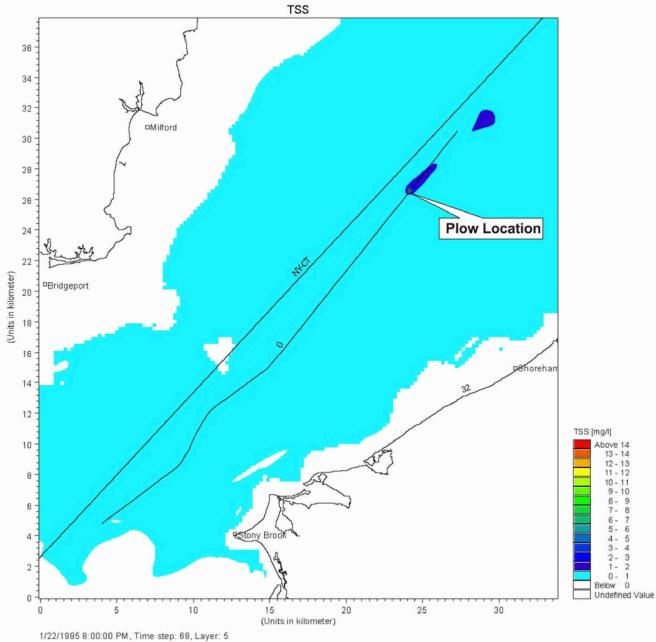


Figure 67. Mid-depth at Timestep = 68 (60 hours into airlift operation at Cross Sound Cable crossing)

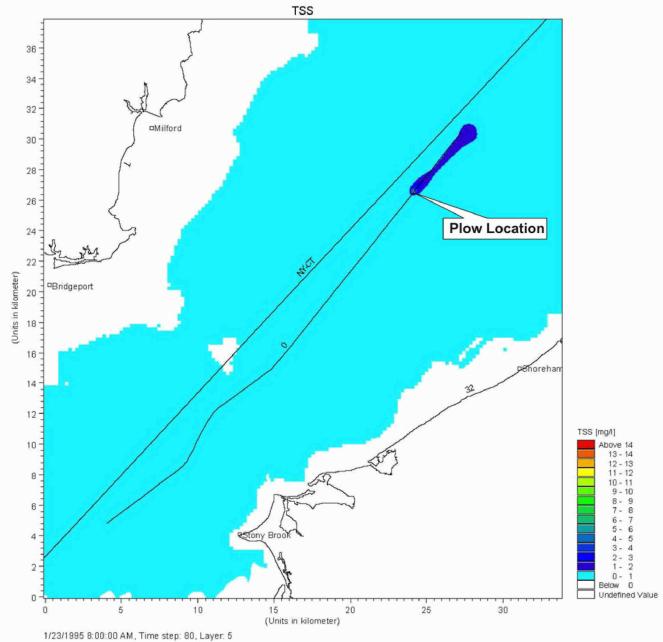


Figure 68. Mid-depth at Timestep = 80 (end of airlift operation at Cross Sound Cable crossing)

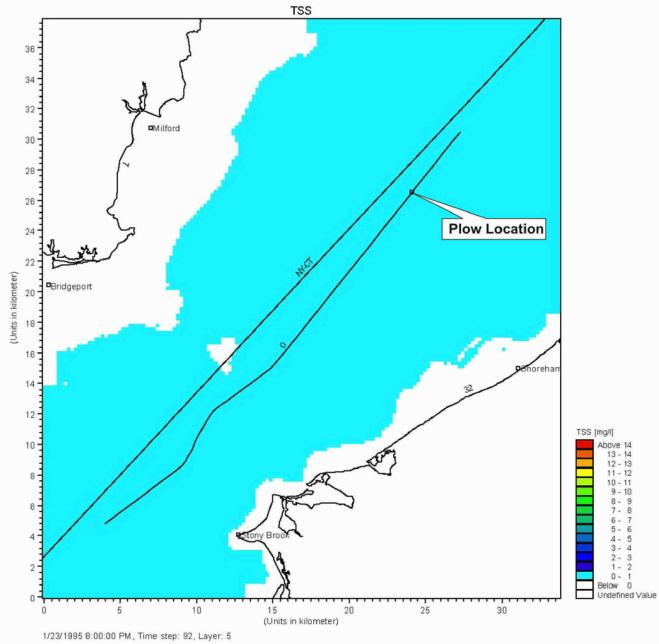


Figure 69. Mid-depth at Timestep = 92 (12 hours after end of airlift operation)

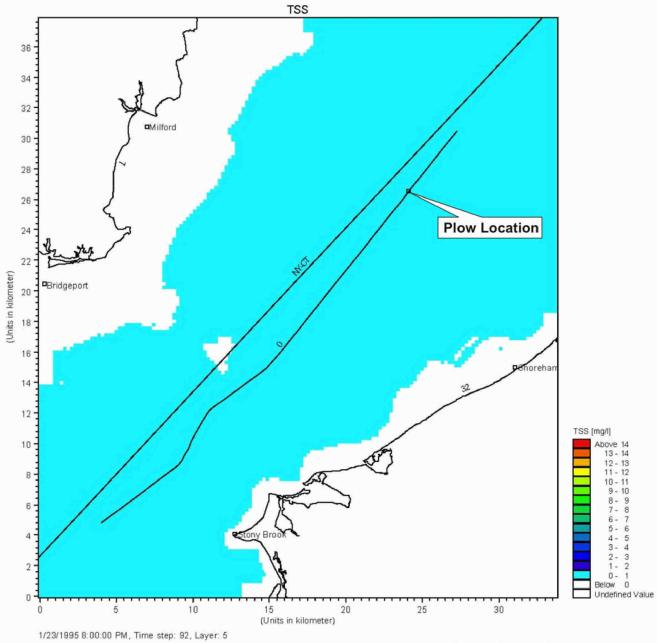


Figure 70. Bottom at Timestep = 8 (start of airlift operation at Cross Sound Cable crossing)

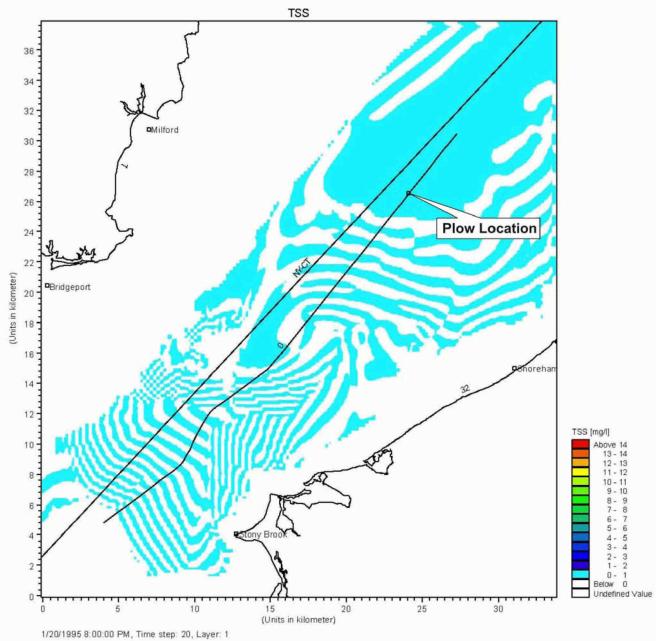


Figure 71. Bottom at Timestep = 20 (12 hours into airlift operation at Cross Sound Cable crossing)

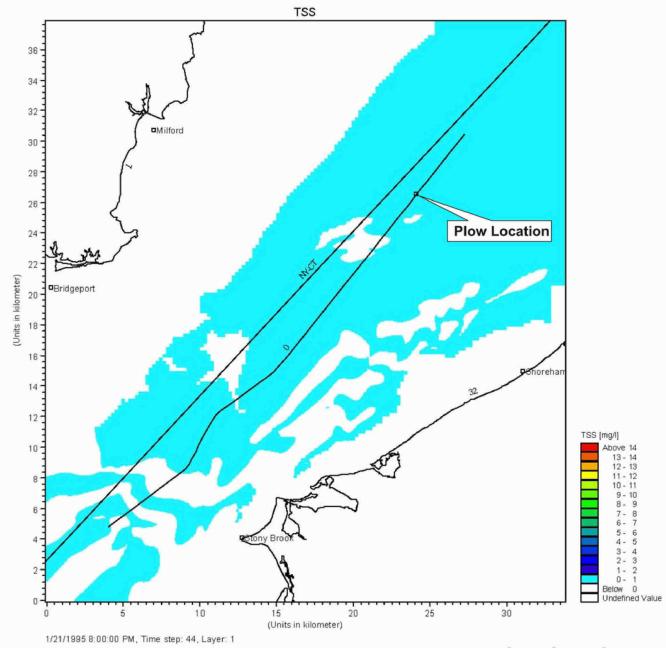


Figure 72. Bottom at Timestep = 44 (36 hours into airlift operation at Cross Sound Cable crossing)

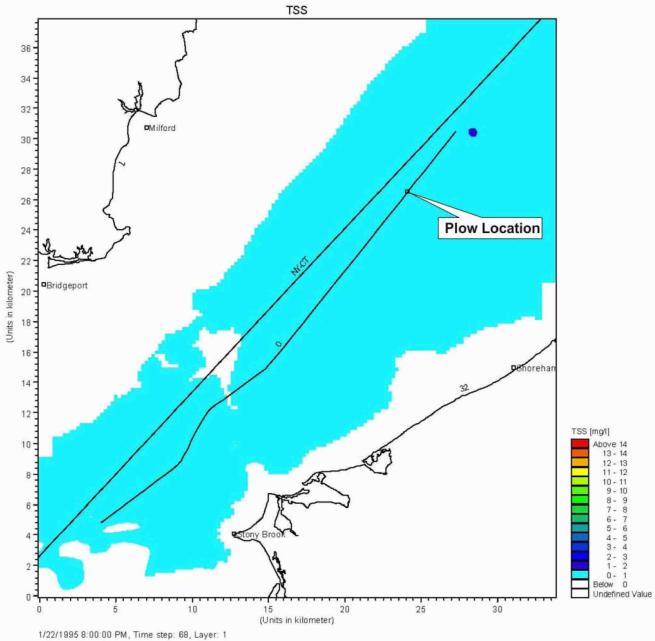


Figure 73. Bottom at Timestep = 68 (60 hours into airlift operation at Cross Sound Cable crossing)

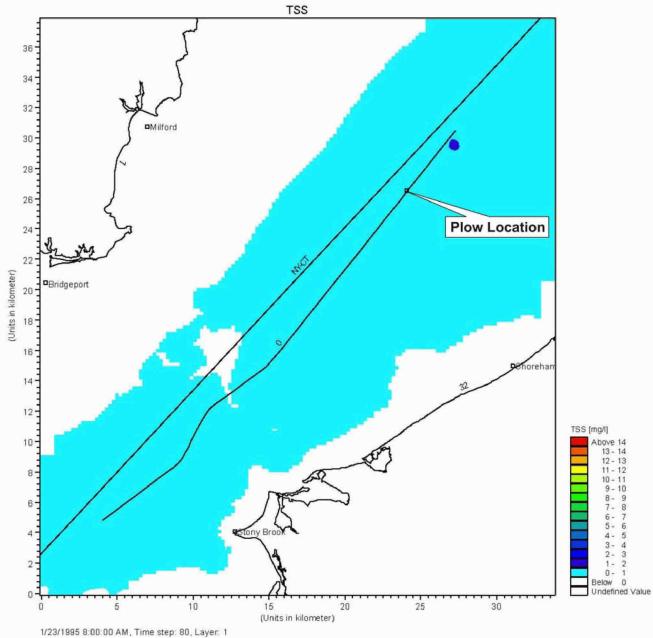


Figure 74. Bottom at Timestep = 80 (end of airlift operation at Cross Sound Cable crossing)

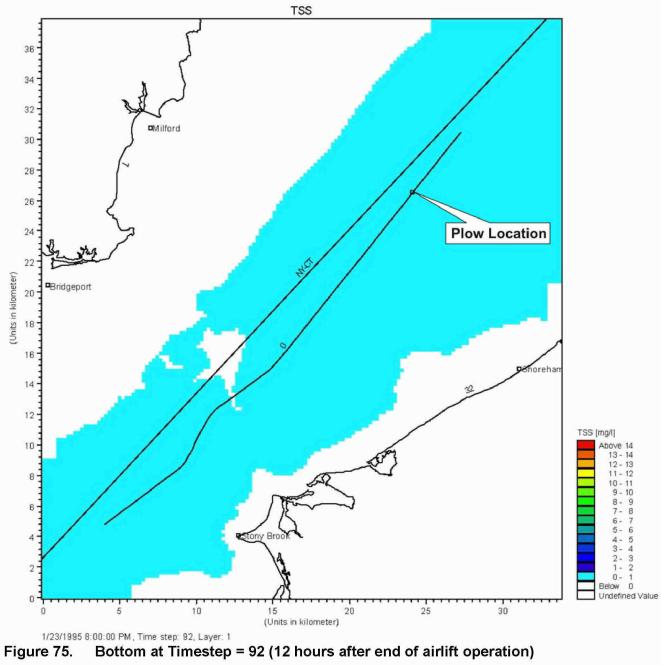


Figure 75.

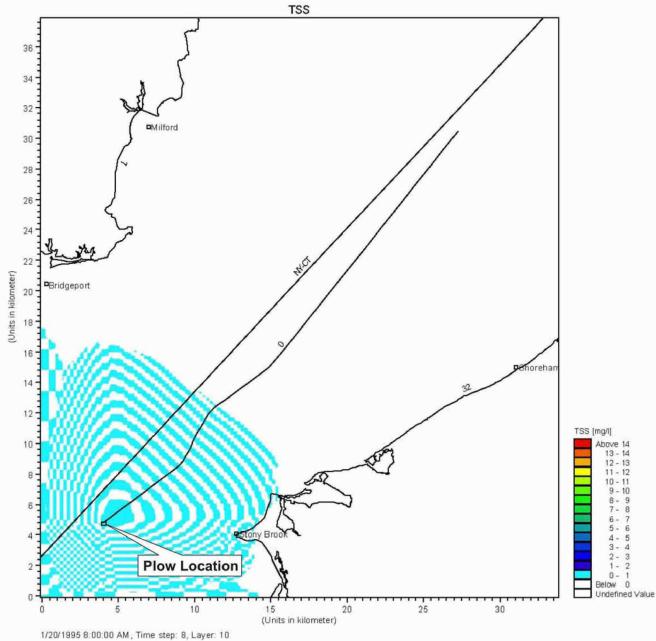


Figure 76. Surface at Timestep = 8 (start of airlift operation at IGTS tie-in)

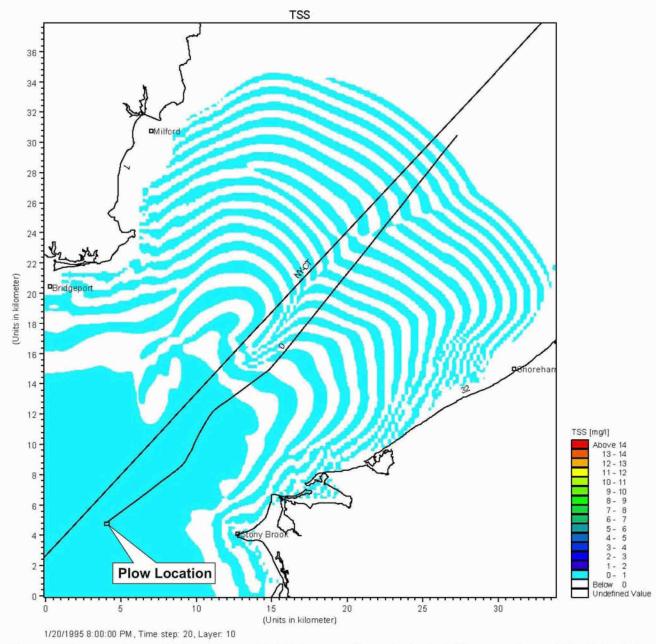
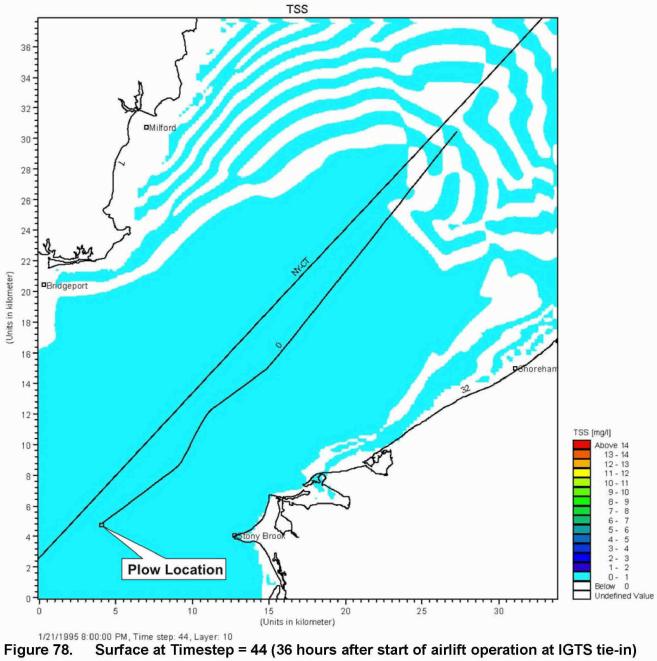


Figure 77. Surface at Timestep = 20 (12 hours after start of airlift operation at IGTS tie-in)



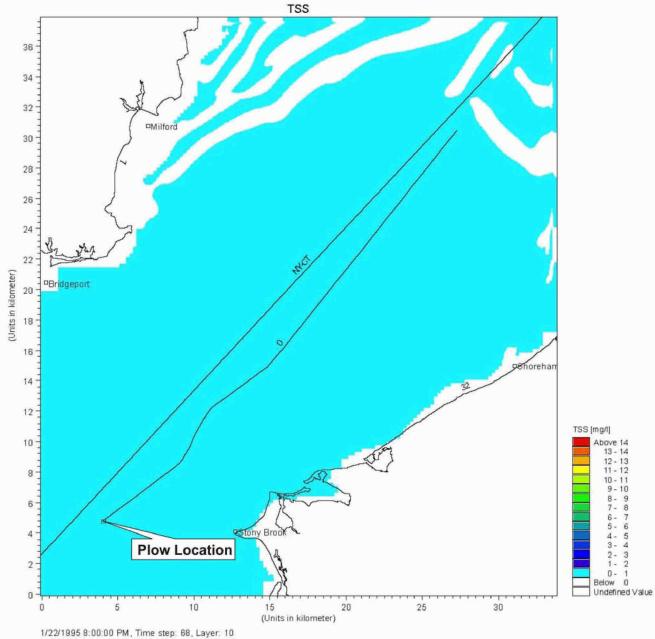


Figure 79. Surface at Timestep = 68 (60 hours after start of airlift operation at IGTS tie-in)

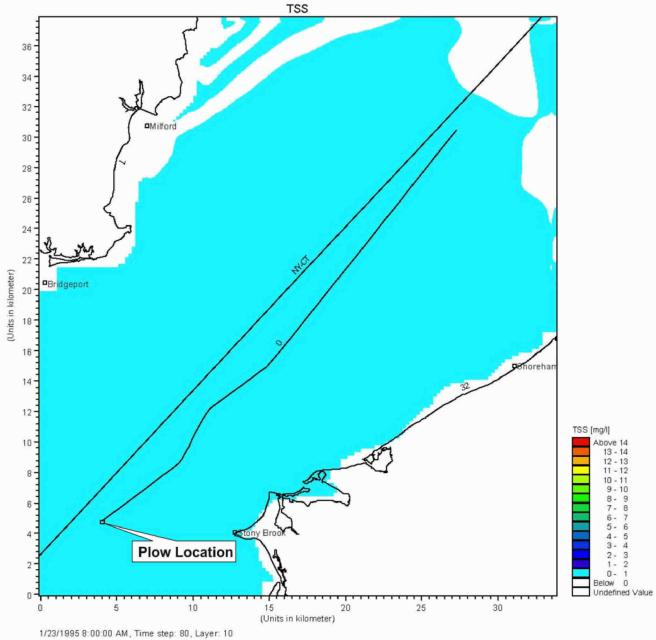


Figure 80. Surface at Timestep = 80 (end of airlift operation at IGTS tie-in)

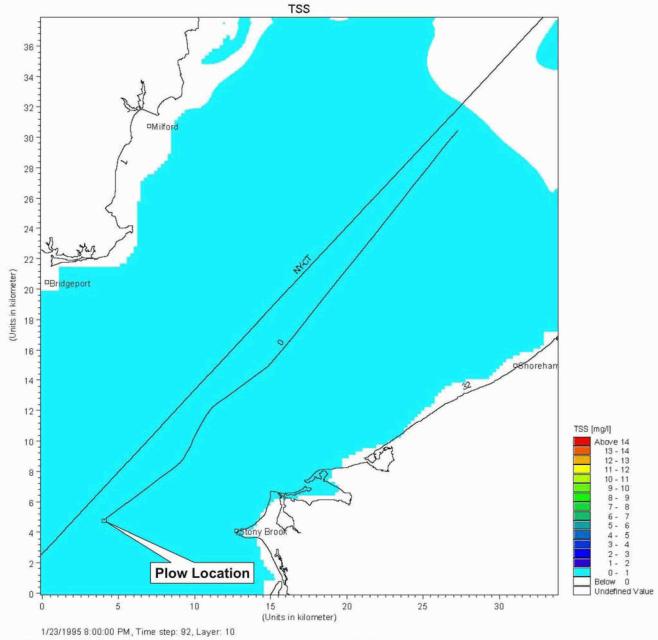


Figure 81. Surface at Timestep = 92 (12 hours after end of airlift operation)

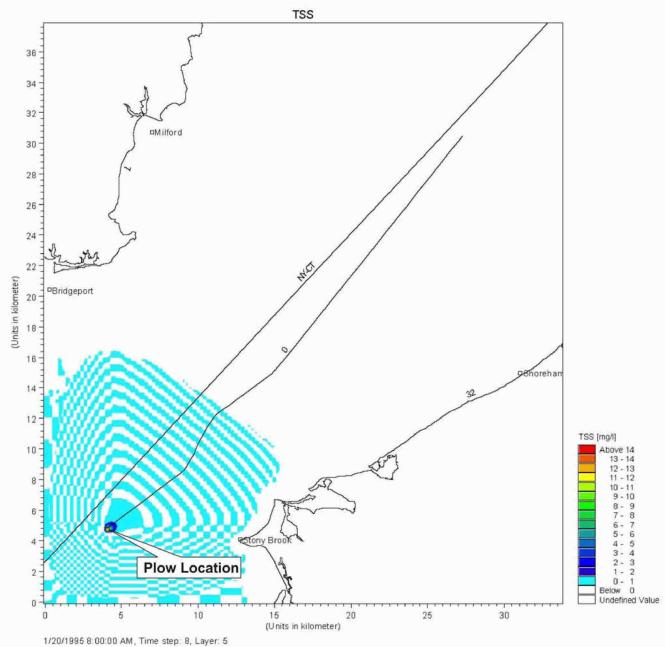


Figure 82. Mid-depth at Timestep = 8 (start of airlift operation at IGTS tie-in)

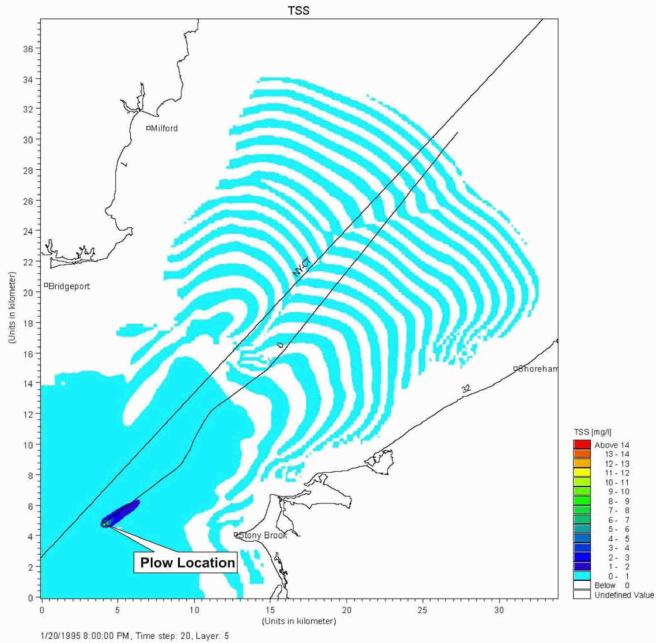


Figure 83. Mid-depth at Timestep = 20 (12 hours after start of airlift operation at IGTS tie-in)

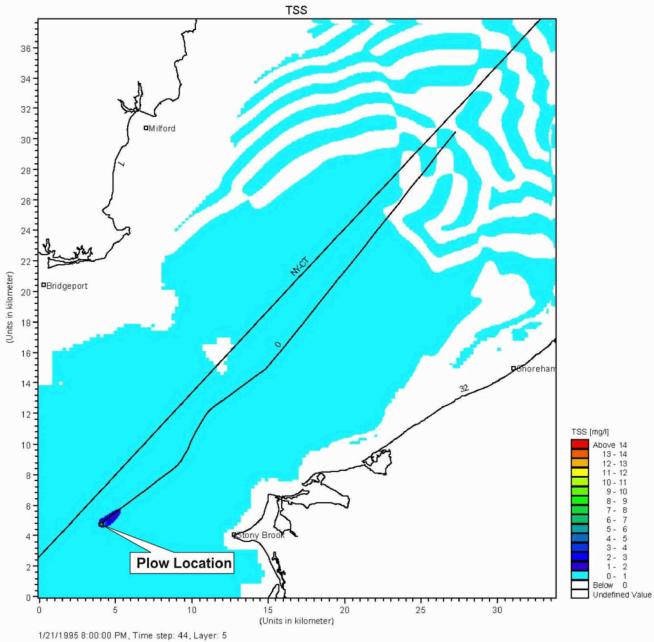


Figure 84. Mid-depth at Timestep = 44 (36 hours after start of airlift operation at IGTS tie-in)

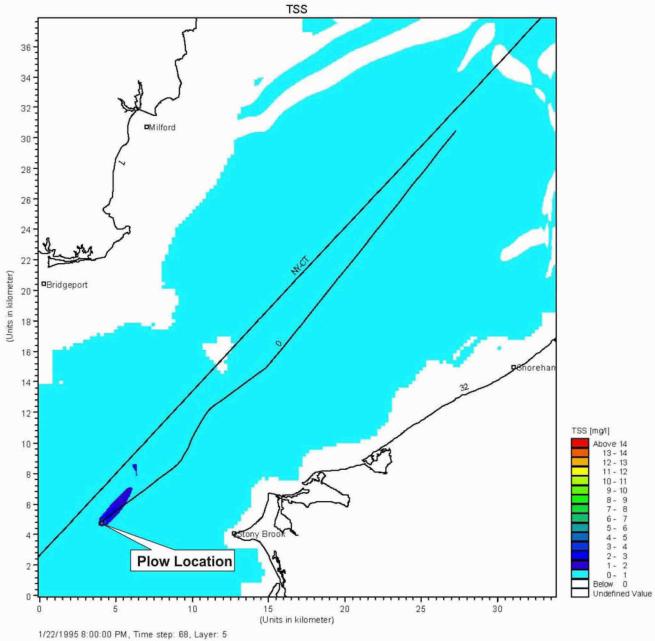


Figure 85. Mid-depth at Timestep = 68 (60 hours after start of airlift operation at IGTS tie-in)

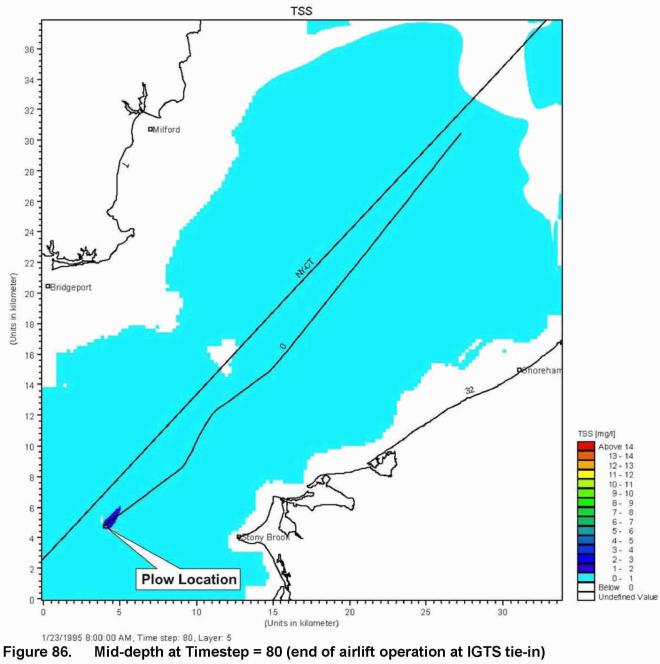


Figure 86.

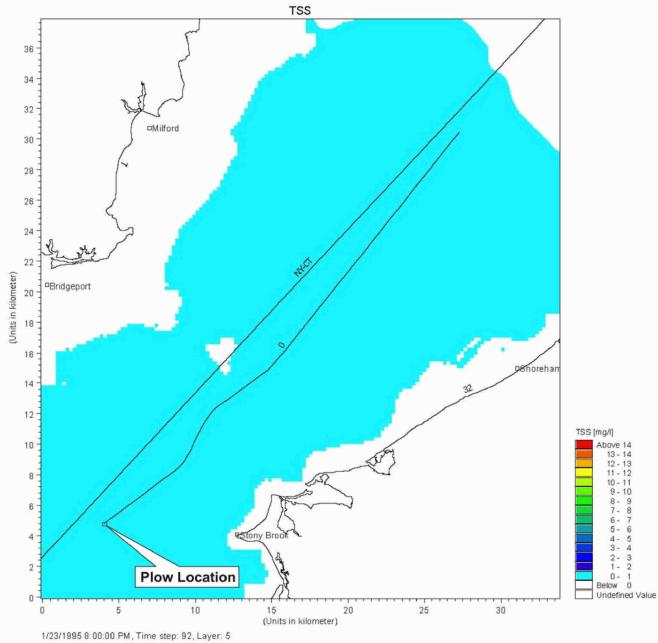


Figure 87. Mid-depth at Timestep = 92 (12 hours after end of airlift operation at IGTS tie-in)

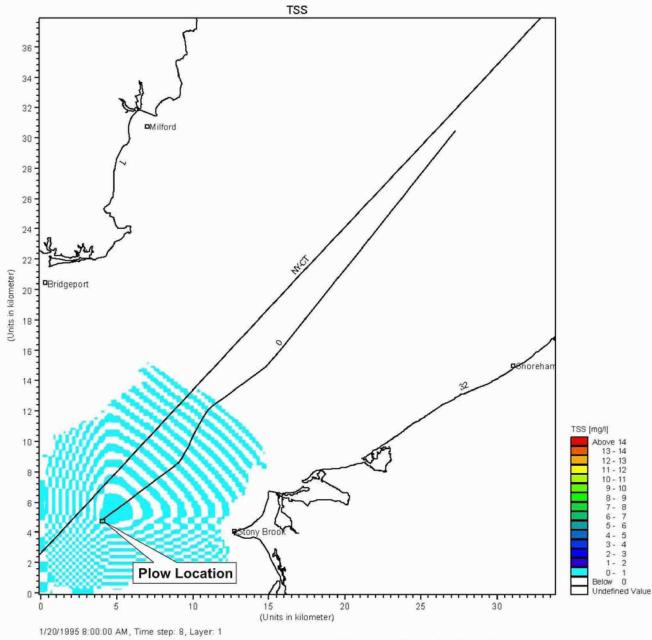


Figure 88. Bottom at Timestep = 8 (start of airlift operation at IGTS tie-in)

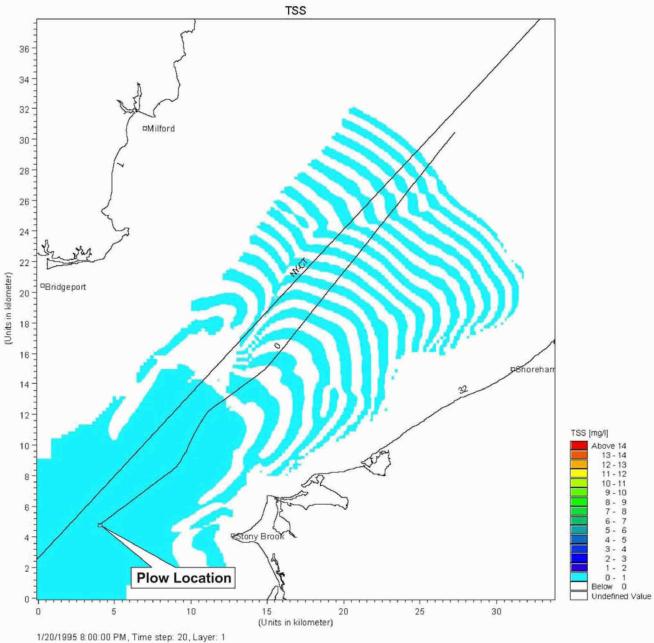


Figure 89. Bottom at Timestep = 20 (12 hours after start of airlift operation at IGTS tie-in)

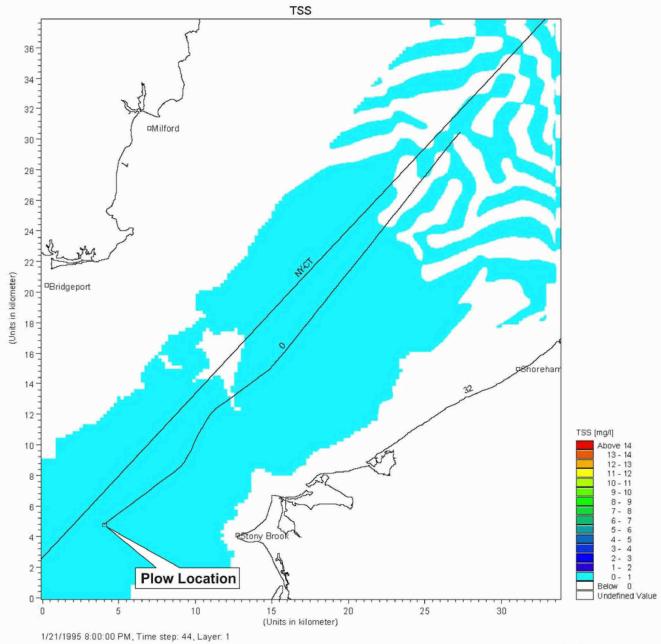


Figure 90. Bottom at Timestep = 44 (36 hours after start of airlift operation at IGTS tie-in)

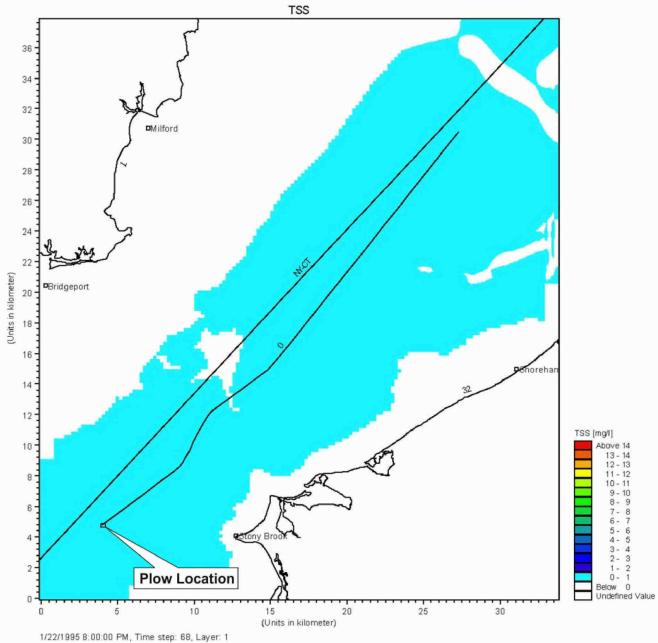


Figure 91. Bottom at Timestep = 68 (60 hours after start of airlift operation at IGTS tie-in)

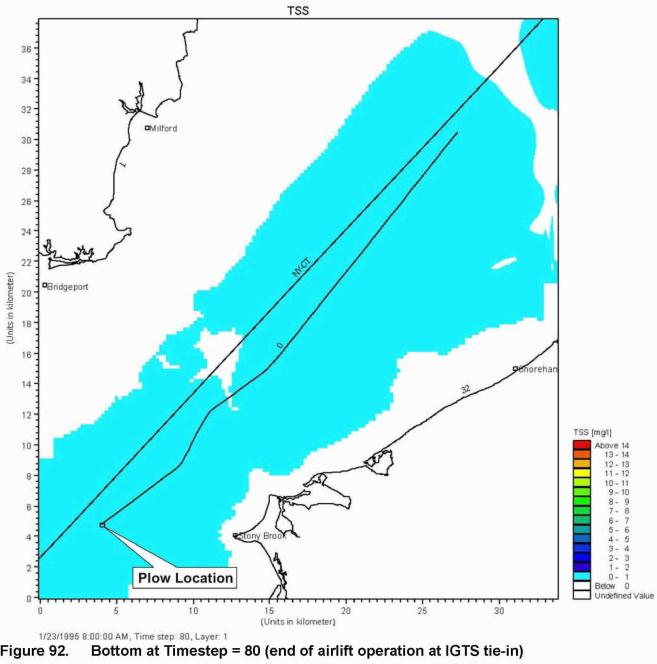


Figure 92.

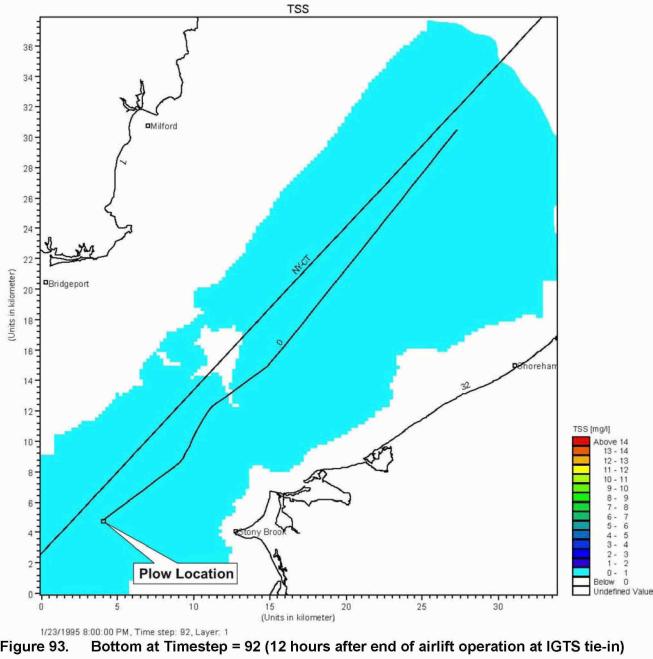


Figure 93.

5. CONCLUSIONS

The results of the modeling analysis show that the trench construction will result in minimal TSS increases. Temporary spikes of TSS are evident along the bottom associated with the plowing operations, but these are extremely short lived. In the mid-depth range, spikes are less pronounced but still evident. In the immediate vicinity of the plow, only concentration increases of 10-15 mg/L are predicted, and only in isolated areas. Ambient TSS concentrations in Long Island Sound are typically in the 20-30 mg/L range², although much higher TSS levels could be expected with storms that can both increase bottom sediment disturbance, and introduce greater sediment loads into the Sound via non-point source runoff, and increased sediment loads from the larger river systems that outlet to the Sound. It is therefore expected, given the depths in the Sound along the planned route, no visible plume would be evident at the surface. This is because the increases in TSS predicted by the analysis would fall within the variation in ambient TSS values.

At mid depth the results also show relatively small increases in TSS, usually 5 mg/L or less. Again, this is within the expected ambient TSS variations, and so no distinct plume would be visible even at mid depth.

The reason resulting TSS concentrations remain low is the effect of the tidal shifts in current direction, which allow maximum dispersion of the resuspended material. This is in direct contrast, for example, to a river, where the current is unidirectional and the resulting plume is well established.

Based on the modeling results, the increases in TSS will not have appreciable impact in sedimentation rates immediately outside the construction corridor, and in fact will not differ appreciably from background levels. As such, while the introduction of some suspended material is unavoidable during construction activities, by using subsea plowing, significant introduction of sediment into the water column is avoided. These modeling results demonstrate that increased sediment in the water column resulting from construction of the Project would not have a significant adverse impact to the water column, or to existing ecosystems within Long Island Sound.

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² New York City Department of Environmental Protection. 2002. Harbor Survey Data, 1999-2004.

Addendum to the Water Quality/Sedimentation Modeling Report

Supplemental TSS Figures

The Water Quality Modeling and Sedimentation Modeling report prepared for the project contained 100 figures. Most of these were plots showing suspended TSS concentrations. To make comparisons between plots easier, one standard scale was used throughout the report. In some instances, TSS values exceeded the scale maximum of 14 mg/L. In these cases the figures were replotted on a new, expanded TSS scale that ranges up to 160 mg/L. The new plots also zoomed in on the high values.

In this report the original TSS plot is shown first, and then the new, detailed plot follows. Added to the original plot is a box showing the area of detail encompassed by the new plot.

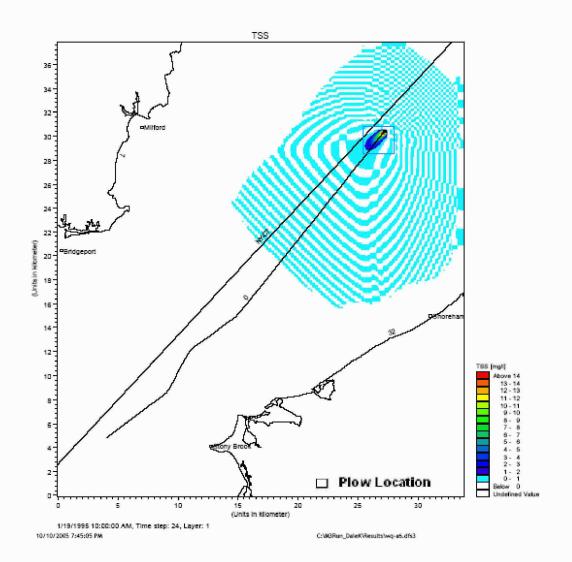


Figure 1. Bottom TSS at timestep=24 (start of plowing). (Figure 22 in Water Quality Report)
Insert shows area of detail.

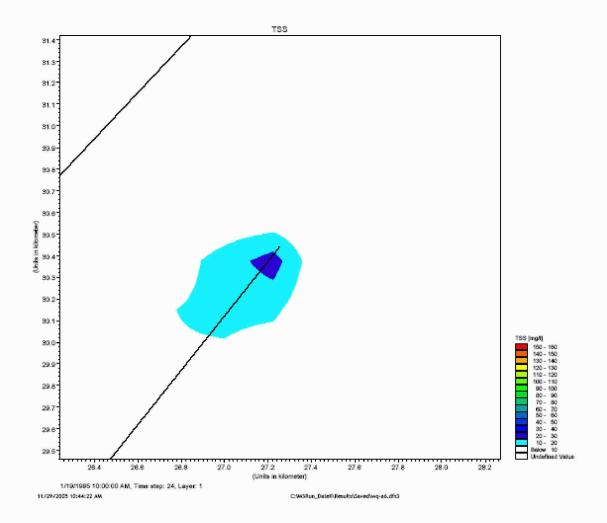


Figure 2. Expanded bottom TSS scale at timestep=24

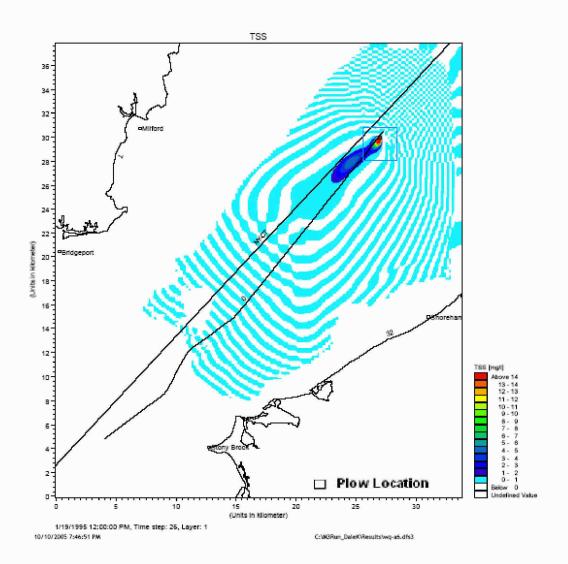


Figure 3. Bottom TSS at timestep=26 (Figure 23 in Water Quality Report) Insert shows area of detail.

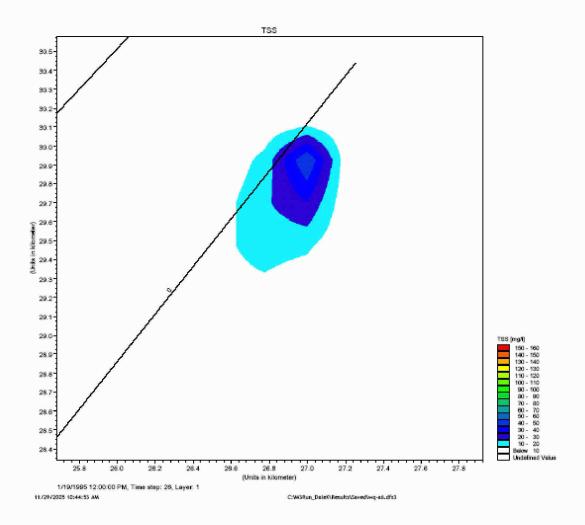


Figure 4. Expanded bottom TSS scale at timestep=26

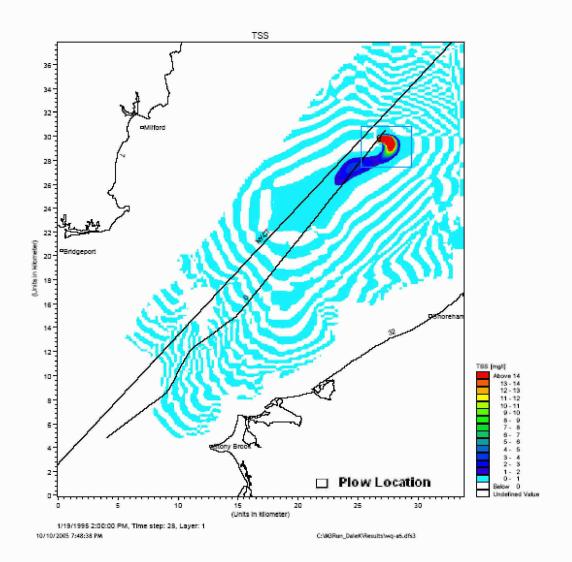


Figure 5. Bottom TSS at timestep=28 (Figure 24 in Water Quality Report) Insert shows area of detail.

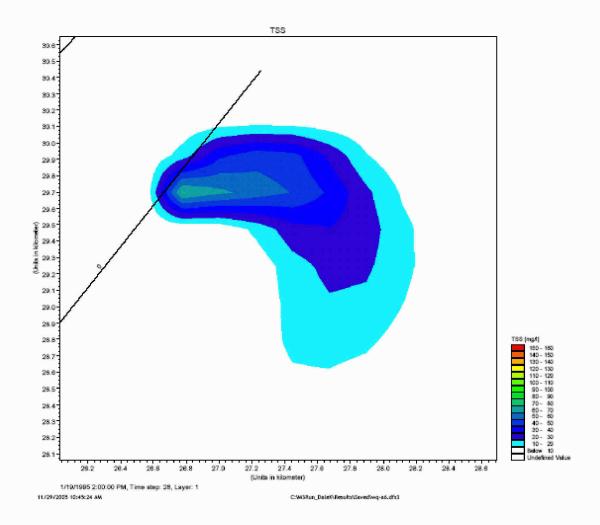


Figure 6. Expanded bottom TSS scale at timestep=28

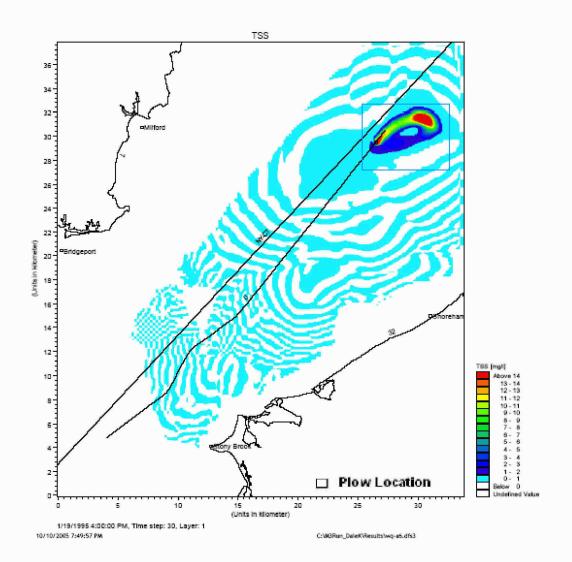


Figure 7. Bottom TSS at timestep=30 (Figure 25 in Water Quality Report) Insert shows area of detail.

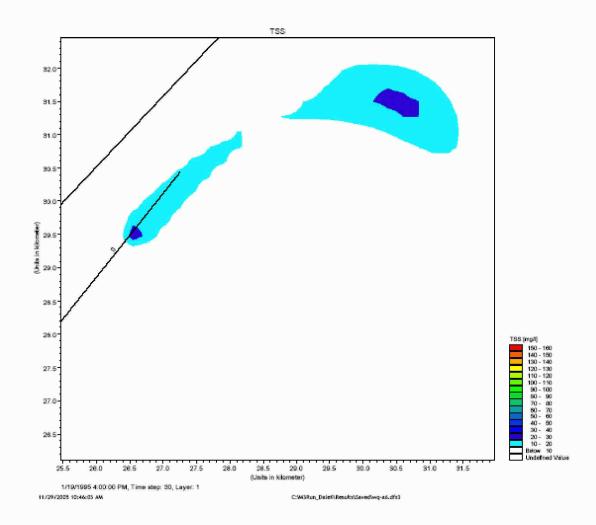


Figure 8. Expanded bottom TSS scale at timestep=30

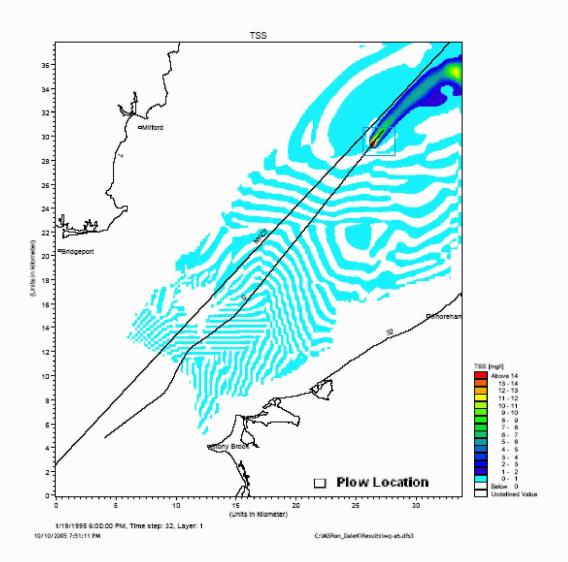


Figure 9. Bottom TSS at timestep=32 (Figure 26 in Water Quality Report) Insert shows area of detail.

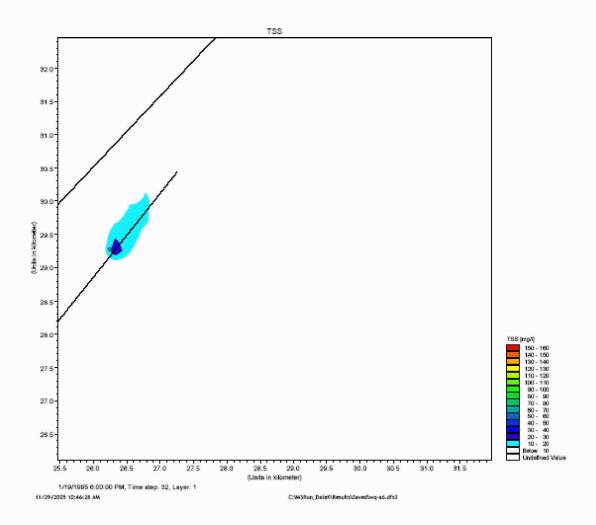


Figure 10. Expanded bottom TSS scale at timestep=32

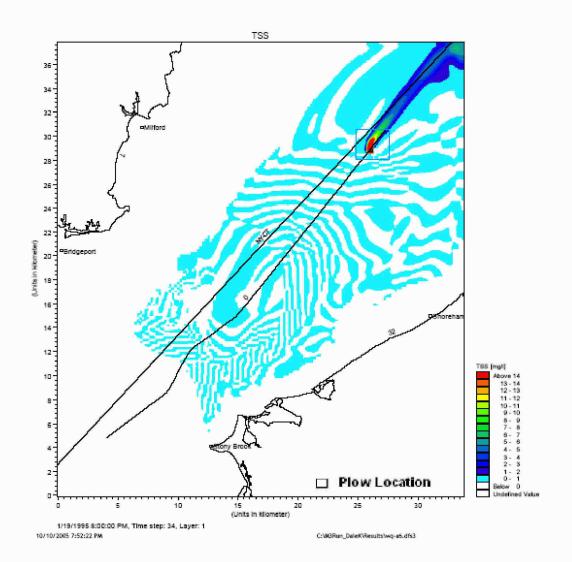


Figure 11. Bottom TSS at timestep=34 (Figure 27 in Water Quality Report) Insert shows area of detail.

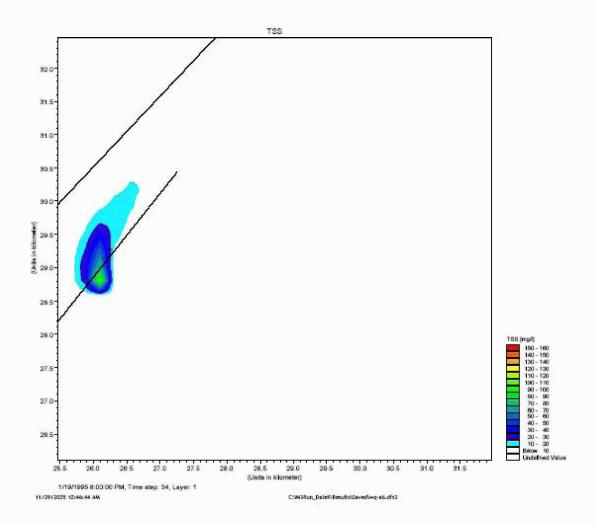


Figure 12. Expanded bottom TSS scale at timestep=34

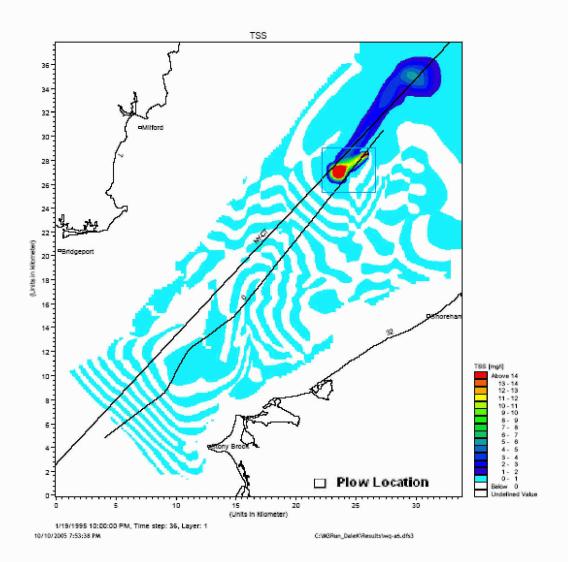


Figure 13. Bottom TSS at timestep=36 (Figure 28 in Water Quality Report) Insert shows area of detail.

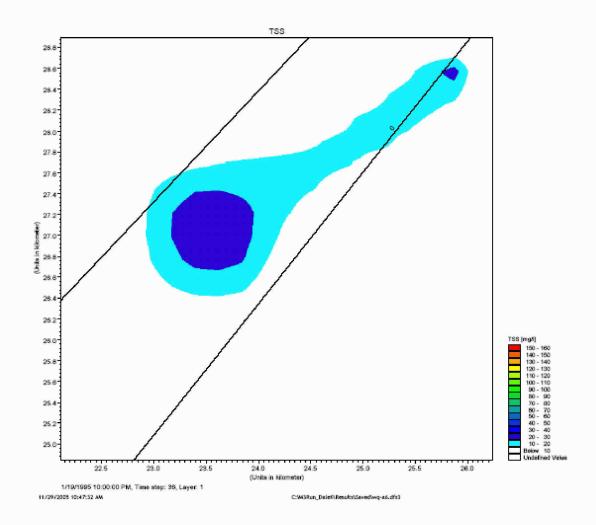


Figure 14. Expanded bottom TSS scale at timestep=36

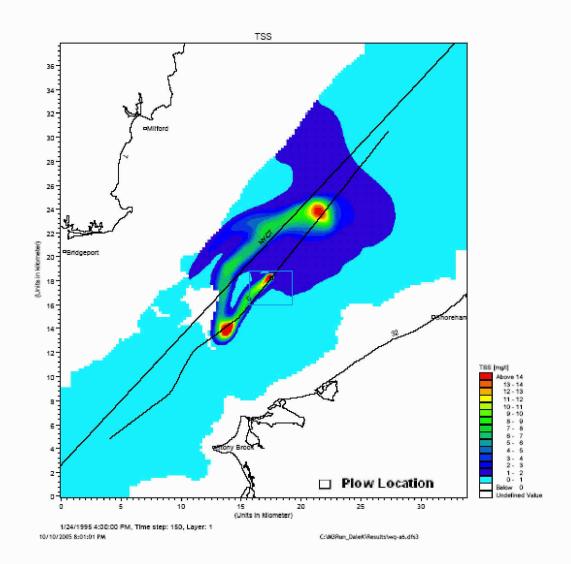


Figure 15. Bottom TSS at timestep=150 (middle of route) (Figure 45 in Water Quality Report) Insert shows area of detail.

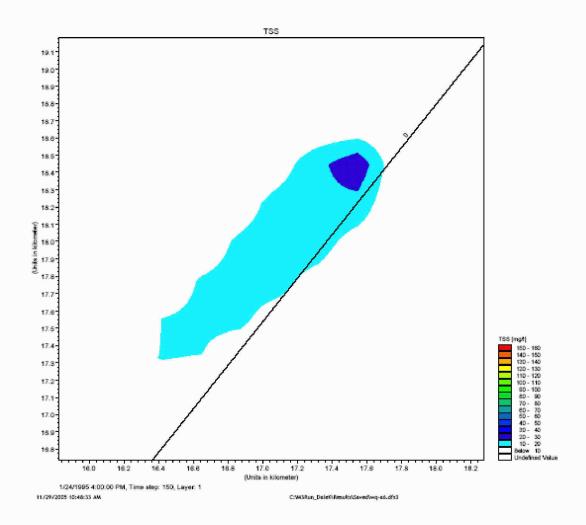


Figure 16. Expanded bottom TSS scale at timestep=150

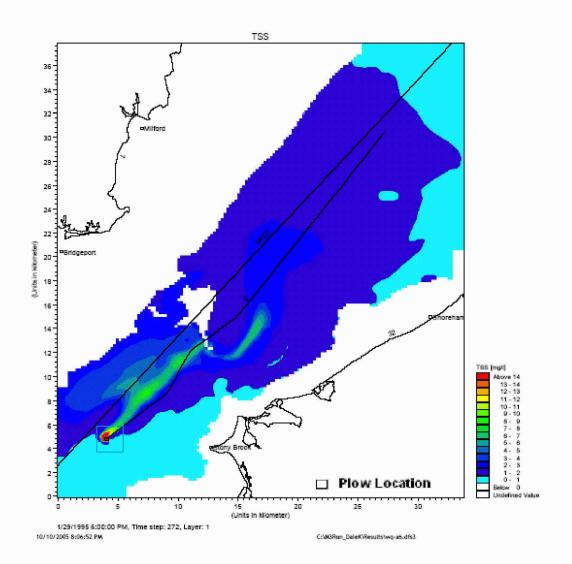


Figure 17. Bottom TSS at timestep=272 (end of plowing) (Figure 48 in Water Quality Report)
Insert shows area of detail.

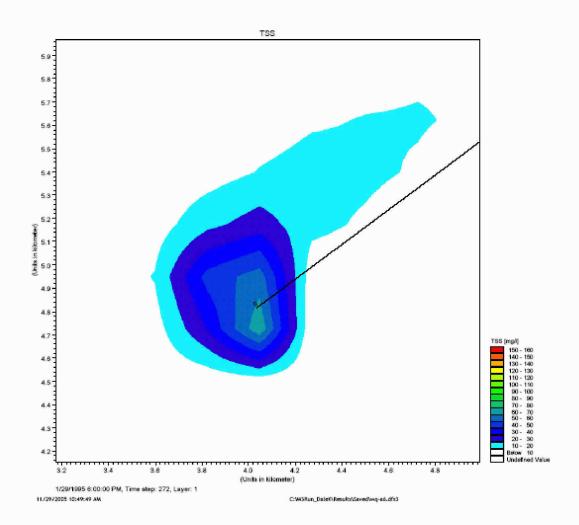


Figure 18. Expanded bottom TSS scale at timestep=272

Appendix A **Modeling Protocols**

Sediment and Contaminant Fate and Transport Modeling Protocol Broadwater LNG Project Long Island, New York

April 2005

Prepared for:

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

and

UNITED STATES ARMY CORPS OF ENGINEERS

Prepared by:

LMS One Blue Hill Plaza Pearl River, New York 10965

and

ECOLOGY AND ENVIRONMENT, INC. 368 Pleasant View Drive Lancaster, New York 14086

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Introduction

Broadwater Energy LLC (Broadwater), a limited liability corporation formed by subsidiaries of TransCanada Corporation and Shell US Gas & Power, is filing an application with the Federal Energy Regulatory Commission (FERC) seeking all of the necessary authorizations to construct and operate a marine liquefied natural gas (LNG) terminal and interconnected subsea pipeline for the importation, storage, regasification, and transport of foreign-source LNG. The Broadwater LNG Project (the Project) will increase the availability of natural gas to the New York and Connecticut markets through an interconnection with the Iroquois Gas Transmission System (IGTS).

The proposed floating storage and regasification unit (FSRU) will be located in Long Island Sound, approximately 9 miles from the shore of Long Island in New York State waters (see Figure 1). The FSRU will be designed to receive, store, and regasify LNG at an average throughput of 1.0 billion cubic feet per day (bcfd) and will be capable of delivering a peak throughput of 1.25 bcfd. The Project will deliver the regasified LNG to the existing onshore natural gas pipeline system via a subsea interconnection to the Iroquois Gas Transmission System (IGTS) pipeline.

The FSRU will be moored in place using a yoke mooring system (YMS) that allows the FSRU to pivot around the mooring structure with changing wind and current patterns. The YMS includes a stationary tower structure, secured to the seafloor with four legs. The total seafloor area under the structure is approximately 7,000 square feet (630 square meters [m²]). The connection between the FSRU and the proposed subsea delivery pipeline is at the tower structure.

The proposed delivery pipeline will be a 30-inch-diameter subsea natural gas pipeline designed to deliver the vaporized natural gas to the existing pipeline grid. The pipeline will be installed beneath the seafloor from the FSRU mooring structure to an interconnection at the existing 24-inch-diameter IGTS subsea pipeline, approximately 22 miles west of the proposed FSRU site.

Construction of the proposed Project will result in some re-suspension of sediments during installation of the mooring structure and trenching operations required for the proposed pipeline. While Broadwater will coordinate with the

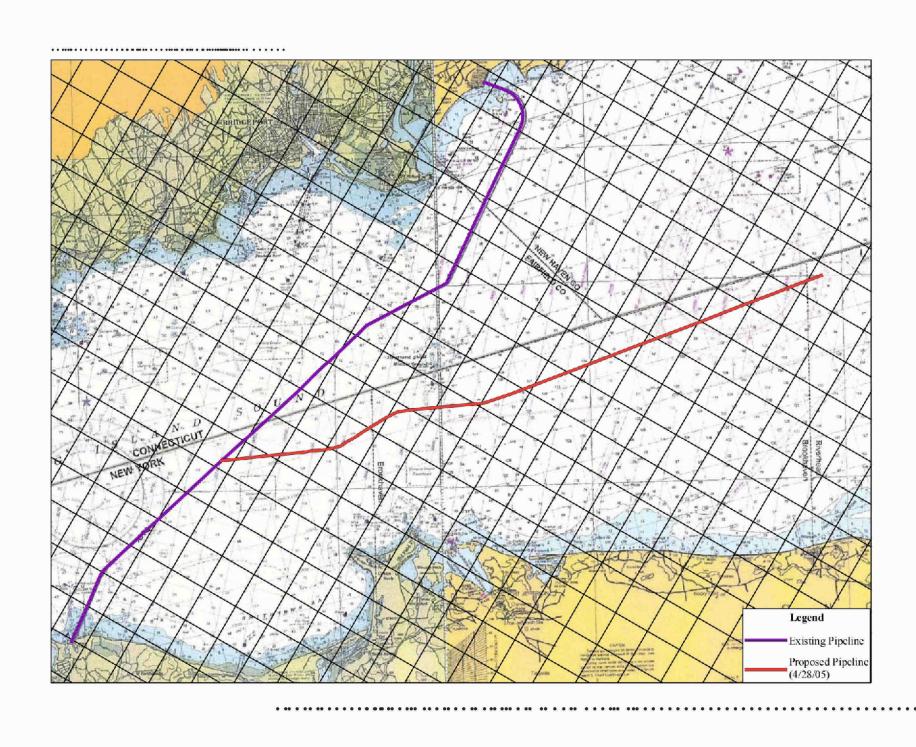




United States Army Corps of Engineers (USACE), New York State Department of Environmental Conservation (NYSDEC), and New York State Department of State (NYSDOS) to develop installation methodologies and timing that minimizes impacts on marine resources, installation at any time has the potential to impact resources through resuspension of sediments. Re-suspension of sediments has the potential to affect water quality through increased turbidity and through reintroduction of buried contaminants to the water column. In spring 2005, Broadwater will collect environmental samples to determine existing contaminant levels in sediments to the proposed excavation depth along the entire proposed pipeline route.

Broadwater proposes to model the fate and transport of suspended sediments and contaminants to determine the potential for water quality impacts and the potential impacts on marine resources from sediment and contaminant deposition.

Broadwater also proposes to use the existing MIKE3 model which encompasses New York Harbor-Long Island Sound to determine sediment fate and transport, as well as potential water quality impacts associated with installation of the Project. A description of the MIKE3 model, the technical approach used to run the model, and the development and verification of the model are presented in this protocol.



MIKE3 Model Selection and Description

Several models are available that could be used to evaluate the sedimentation resulting from the installation of the Project (i.e., DREDGE, MIKE3). Broadwater is proposing to the use the MIKE3 model to best address the conditions that are anticipated to occur as a result of installation of the Project. The MIKE3 model is a three-dimensional, time-variable, continuous-simulation model that takes Long Island Sound hydrodynamics into account. The model can determine the fate and transport of sediments and contaminants to determine potential water quality impacts resulting from installation of the Project. In essence, the model treats the installation of the pipeline as a moving point source that releases a mass of solids and particulates and/or dissolved contaminants into specific model cells that overlie the trench. Mass loadings are then used to generate constituent concentrations in the water column, transported by prevailing currents and dispersion. Particulate material will also be tracked until redeposited back to the seafloor..

MIKE3 is a professional engineering software package for three-dimensional, free-surface flows. It is applicable to simulations of hydraulics, water quality, and sediment transport in rivers, lakes, estuaries, bays, coastal areas, seas, and other water bodies. MIKE3 simulates unsteady flow, taking into account density variations, bathymetry, and external forcing such as meteorology, tidal elevations, currents, and other hydrographic conditions.

MIKE3, developed by the Danish Hydraulic Institute, is the result of more than 10 years of continuous development and has been tuned through the experience gained from many applications worldwide. The model was and has been used in over 100 countries and several thousand applications.

While other modeling packages can provide similar 3-dimensional evaluation of the dispersion, MIKE3 includes the added benefit of being able to model temporally the movement of construction impacts along the linear pipeline corridor.

Table 1 identifies key features of the model, as well as specific model inputs and outputs.



2. MIKE3 Model Selection and Description

Table 1 MIKE3 Model Features, Input, and Output

Model Features	Inputs	Output
• • 3-dimensional	• • Long Island Sound	•• The fate and transport of
• • Time-variable	hydrodynamics	sediments and
• • Continuous simulation	• • Tidal elevations	contaminants for use in
• • Variable cell size	•• Wind speed and direction	determining potential
	• • Atmospheric pressure	impacts
	• • River flows	
	• • Anticipated volume of	
	displaced material	
	• • Mass of displaced material	
	based on site-specific	
	density and porosity of	
	sediment	
	• • Sediment contaminant	
	concentrations	
	• • Rate of trenching	
	operation	

Regional Application of MIKE3

The United States Army Corps of Engineers, New York District, commissioned the New York/New Jersey Harbor Partnership to develop a 3-dimensional, hydrodynamic water quality model of the waters in and around New York-New Jersey Harbor, including Long Island Sound. The model was developed to provide the Corps with a flexible, comprehensive model that could be used to evaluate ongoing Corps projects in these waters. The bathymetry and computational grid for the MIKE3 model were originally developed for the New York and New Jersey Harbor Navigation Study.

Once the model was developed, it was extensively calibrated and verified for both hydrodynamics and water quality throughout the New York/New Jersey region. The model was calibrated and validated using field data collected in 1991 and 1995. The data collected included measured surface elevations, currents temperatures, and salinities at a number of locations within the modeled area. The model results also were compared with data available from the National Oceanic and Atmospheric Administration (NOAA), which consisted of measured and predicted surface elevations and predicted currents throughout the model domain. Comparisons were made for all available fixed measurement stations. Additional comparisons were made for predicted water surface elevation/current stations. Detailed graphical comparisons and statistical analyses were performed, which showed that the model was successfully calibrated to the available data. The validation results were as good, or better, than the calibration results.

The details of the model's calibration and verification are provided in NY-NJ Harbor Partnership - Hydrodynamic and Water Quality Modeling: Final Report; Model Calibration, Verification and Application, May 2004.

The model development was coordinated with a number of federal and state agencies, including USACE, New York District; USACE Waterways Experiment Station, Vicksburg, Mississippi; NYSDEC; the New York City Department of Environmental Protection; the New Jersey Department of Environmental Protection; the United States Geological Survey (USGS); the National Weather Service; and NOAA.



3. Regional Application of MIKE3

A national expert panel established by USACE, New York District, provided technical review.

Since completion of the model's development in 2003, it has been used on numerous projects for USACE. Lawler, Matusky and Skelly Engineers (LMS), the consultant that will run the model for Broadwater, has used the model to evaluate the effects of projects in the following water bodies:

- • Arthur Kill,
- • Kill Van Kull,
- •• The waters off Swinburne Island,
- • Newark Bay,
- • Ambrose Channel,
- • New York Bight,
- • The Inner Harbor,
- • Raritan Bay,
- • Long Island Sound,
- • Hudson River estuary, and
- •• The East River.

Technical Approach

Resolution

The total spatial coverage of the existing New York-New Jersey Harbor MIKE3 model is 350 km by 220 km, with a total of four nested high-resolution grids within the modeling domain, primarily in the New York Harbor area. The existing MIKE3 model for the New York-New Jersey Harbor Navigation Study relied primarily on a 2,025-m grid resolution for the central and eastern portions of Long Island Sound, as this was not the focus of the Harbor Navigation Study, the project for which the MIKE3 model was originally applied to. The MIKE3 model provides the ability to establish varying model resolutions based on proximity to the project area and specific contaminants of concern. For the purposes of this Project, additional resolution around the area of interest along the pipeline route, down to 75-m cell sizes, will be included for this project to better model closerange dispersion of sediments resuspended by installation activities. Based on modeling for previous projects proposed in the Sound (using other modeling protocols), dispersion from installation activities was modeled to extend less than 2,000 feet from the centerline during jetting installation, and less than 1,300 feet during mechanical dredging. As such, application of the MIKE3 model for the Project area will need to consider a much finer resolution than the existing 2,025m grid. The MIKE3 model also has 10 vertical layers with a vertical resolution of 2 m, which will allow the sediments to be tracked in 3 dimensions.

The volume of sediments and contaminants anticipated to be resuspended in the water column as a result of installation of the pipeline will be input into the model. Broadwater has not yet finalized installation methodologies and will coordinate with reviewing agencies to address agency concerns during the process of selecting specific installation methodologies. The volume of sediment anticipated to be displaced will based on the trenching technology used, the dimensions of the trench, and the porosity of the sediment. This information will be available following determination of initial pipeline design and completion of field sample analysis.

The mass of sediment released will be calculated based on the volume displaced and the density and porosity data collected as part of the project-specific sediment sampling plan.



4. Technical Approach

The rate at which the trenching operation will move, which will be based on estimates supplied by Broadwater, will be input into the model.

The hydrodynamics of Long Island Sound were built into the model when it was created and were calibrated to the existing velocity, temperature, and salinity measurements. The existing model domain in the vicinity of the project is shown on Figure 1. The figure shows that the existing model has ample spatial coverage for this project area. In addition, Broadwater will collect current, temperature, and salinity data during the spring 2005 field season, which will provide for quality assurance/quality control (QA/QC) and verification of the established modeling parameters.

Model Operations

Trenching Operation Simulation Procedure

The MIKE3 model will simulate the moving trenching operation along the entire pipeline route. Each model run will be continuous and will begin two tidal cycles before commencement of trenching operations. The model will account for sediment resuspended during the trenching operation and will consider sediment advection, dispersion, settling and resuspension to calculate how the released material will behave.

The model will continuously track the resulting sediment plume, both in the water column and as it is redeposited back to the bottom. The plume will be continuously simulated throughout the tidal cycles, allowing for cumulative effects to be accounted for. The model simulation will continue for two tidal cycles after completion of the trenching operation.

Analysis of Contaminants

Data from the spring 2005 sampling effort will be used to determine whether elevated contaminant levels are present in the Project area. If the data indicate that there is potential for various contaminants to be released into the water column in concentrations that exceed water quality standards, an analysis of the concentration, fate, and transport of those contaminants will be performed. The concentrations of contaminants will be compared to ambient concentrations and state water quality standards.

For the analysis of contaminants, the following additional steps will be required in the model:

- 1. The in situ concentrations of particulate and dissolved toxics will be calculated based on the relevant partitioning theory (either organic or inorganic chemical partitioning).
- 2. The amount of both particulate and dissolved chemical that is resuspended during the trenching operation will be calculated.
- 3. The plume of both particulate and dissolved fractions of the chemical will be tracked in the model. Particulate fractions will be tracked until they are rede-





posited back to the sediment; dissolved fractions will be tracked until they are dispersed in the water column to levels below the water quality standards.

Data Presentation

Following completion of the modeling simulations, a report will be developed that includes the results in a variety of formats, including graphical and nongraphical presentations. The report will outline the determination of mass loading rates, summarize the modeling results, and tabularize the results of the model grid points throughout the Project area for direct comparison to ambient water quality conditions and state water quality standards. Modeled sediment deposition will also be graphically presented to illustrate the extent of anticipated impact.

APPENDIX F GRAIN SIZE ANALYSIS MAY 2005 ENVIRONMENTAL SAMPLING

F-1 PUBLIC

Ecology and Environment ASI Job #25-063 Particle Size Distribution, % Moisture, and TOC Values

Sample	ASI ID#	% Gravel	% Clay	% Silt	% Sand	% Moisture	TOC ppm	% TOC of dry weight
C-1a north	20050483a	0.00	51.7	48.3	0.00	54.7	23,509	2.35
C-1b center	20050483b	0.00	53.5	46.5	0.00	55.0	23,267	2.33
C-1c south	20050483c	0.00	51.3	47.6	1.11	55.9	23,853	2.39
C-2a north	20050356a	0.00	42.7	50.7	6.61	55.5	21,199	2.12
C-2b center	20050356b	0.00	44.9	51.4	3.71	58.1	20,225	2.02
C-2c south	20050356c	0.00	30.6	34.4	35.1	47.3	13,930	1.39
C-3 center	20050357	0.82	35.1	38.7	25.3	46.2	14,349	1.43
C-3a north	20050376a	0.00	29.3	32.0	38.7	44.1	15,000	1.50
C-3b center	20050376b	0.00	34.3	37.9	27.8	49.9	16,885	1.69
C-3c south	20050376c	0.00	36.5	39.4	24.0	50.8	16,655	1.67
C-3c south dup	20050376c	0.00	36.8	36.9	26.2	49.6	,	
C-3c south trip	20050376c	0.00	35.7	35.9	28.4	50.5		
C-4a north	20050355a	0.19	28.1	30.9	40.8	43.9	11,439	1.14
C-4b center	20050355b	0.00	28.5	30.0	41.4	38.9	13,417	1.34
C-4c south	20050355c	0.11	27.5	30.2	42.1	43.1	13,287	1.33
C-4c south dup	20050355c	0.33	29.1	29.8	40.8		-	
C-4c south trip	20050355c	0.37	29.5	32.7	37.4			
C-8a north	20050322a	5.52	28.3	30.3	35.8	43.5	17,951	1.80
C-8b center	20050322b	1.76	37.9	43.1	17.3	49.8	19,037	1.90
C-8b center dup	20050322b	3.22	37.3	41.1	18.3			
C-8b center trip	20050322b	1.74	38.7	43.4	16.2			
C-8c south	20050322c	2.91	33.9	36.4	26.7	45.0	15,078	1.50
C-9a north	20050320a	5.64	31.1	34.6	28.7	46.2	15,545	1.55
C-9b center	20050320b	11.2	24.9	24.5	39.4	42.5	14,896	1.49
C-9c south	20050320c	5.70	27.9	28.5	38.0	39.6	16,481	1.65
C-15a north	20050373a	0.00	36.2	44.8	19.0	50.9	18,718	1.87
C-15b center	20050373b	0.02	38.9	44.9	16.2	50.3	17,601	1.76
C-15c south	20050373c	0.00	35.2	38.0	26.8	47.3	16,889	1.69
C-16a north	20050359a	0.00	43.9	51.1	4.97	50.7	22,469	2.25
C-16b center	20050359b	0.00	40.7	46.7	12.6	50.9	19,619	1.96
C-16c south	20050359c	0.00	39.3	44.0	16.7	50.0	22,630	2.26
C-17a north	20050358a	0.00	41.6	53.3	5.12	53.4	21,762	2.18
C-17b center	20050358b	0.00	47.4	52.6	0.00	52.0	20,874	2.09
C-17b center dup	20050358b	0.00	47.5	52.5	0.00			
C-17b center trip	20050358b	0.00	46.6	53.4	0.00			
C-17c south	20050358c	0.08	44.6	55.3	0.00	53.6	22,565	2.26
C-17c south dup	20050358c					54.2		
C-17c south trip	20050358c					54.0		
C-18a north	20050323a	14.92	9.79	6.79	68.5	27.3	5,122	0.51
C-18b center	20050323b	10.72	12.6	11.4	65.3	29.7	9,398	0.94
C-18c south	20050323c	4.26	20.3	20.6	54.8	31.8	9,184	0.92
C-19a north	20050324a	7.44	12.4	9.27	70.9	27.4	9,617	0.96
C-19b center	20050324b	3.55	16.1	20.2	60.1	31.0	11,260	1.13

Ecology and Environment ASI Job #25-063 Particle Size Distribution, % Moisture, and TOC Values - continued

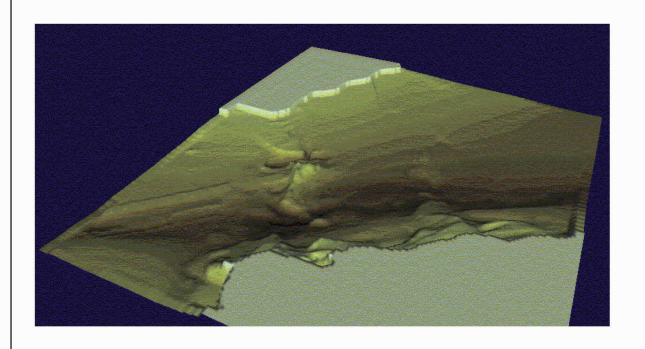
Sample	ASI ID#	% Gravel	% Clay	% Silt	% Sand	% Moisture	TOC ppm	% TOC of dry weight
C-19c south	20050324c	4.79	18.0	20.7	56.6	34.6	12,359	1.24
C-19c south dup	20050324c	3.79	17.9	19.7	58.6	31.8		
C-19c south trip	20050324c	1.66	19.5	22.2	56.6	32.9		
C-20a north	20050352a	4.75	16.5	12.6	66.1	28.1	8,617	0.86
C-20b center	20050352b	6.03	19.9	18.1	56.0	37.6	11,649	1.16
C-20c south	20050352c	4.28	20.7	18.0	57.0	33.4	15,330	1.53
C-21a north	20050487a	7.09	8.05	7.18	77.7	19.8	4,876	0.49
C-21b center	20050487b	5.5	10.4	7.26	76.9	19.6	5,131	0.51
C-21b center dup	20050487b	9.11	10.7	4.53	75.7			
C-21b center trip	20050487b	6.68	10.6	6.88	75.8			
C-21c south	20050487c	10.2	13.7	10.6	65.5	26.8	7,071	0.71
C-22a north	20050488a	0.15	40.4	44.8	14.7	48.9	18,475	1.85
C-22b center	20050488b	0.00	42.7	52.2	5.00	54.8	19,735	1.97
C-22c south	20050488c	0.71	41.7	47.9	9.63	53.8	18,548	1.85
C-23a north	20050491a	0.00	44.1	54.3	1.58	54.6	21,415	2.14
C-23b center	20050491b	0.01	44.7	51.1	4.20	53.2	21,389	2.14
C-23c south	20050491c	0.00	45.0	52.6	2.42	57.4	21,621	2.16
C-24a north	20050492a	0.00	40.9	49.0	10.1	51.9	20,671	2.07
C-24b center	20050492b	0.00	42.1	49.6	8.39	54.0	20,032	2.00
C-24c south	20050492c	0.00	42.4	50.7	6.95	53.6	21,869	2.19
C-25a north	20050494a	0.00	43.7	47.8	8.55	53.4	20,031	2.00
C-25b center	20050494b	0.00	44.5	49.1	6.46	53.7	20,600	2.06
C-25c south	20050494c	0.00	42.7	52.7	4.60	53.3	20,133	2.01
C-26a north	20050493a	0.00	41.3	49.8	8.90	53.5	19,365	1.94
C-26b center	20050493b	0.00	41.8	49.9	8.36	53.7	21,123	2.11
C-26 c south	20050493c	0.00	40.8	49.9	9.33	53.2	20,600	2.06
C-26c south dup	20050493c	0.00	42.0	49.4	8.57	52.9		
C-26c south trip	20050493c	0.13	41.7	48.6	9.58	52.5		
C-27a north	20050489a	0.00	39.0	46.6	14.4	51.3	19,968	2.00
C-27b center	20050489b	0.00	38.7	47.3	14.0	51.5	18,500	1.85
C-27c south	20050489c	0.00	40.5	48.4	11.1	51.7	18,509	1.85
C-28a north	20050490a	0.00	34.1	47.6	18.4	49.6	17,876	1.79
C-28b center	20050490b	0.01	35.9	47.6	16.4	50.1	17,558	1.76
C-28c south	20050490c	0.00	35.1	48.1	16.8	48.8	17,714	1.77
E-1a north	20050321a	8.65	25.7	28.5	37.2	41.0	17,936	1.79
E-1b center	20050321b	11.0	18.2	18.9	51.9	34.6	11,394	1.14
E-1c south	20050321c	8.20	23.0	25.1	43.7	37.0	15,637	1.56
IC-5a north	20050484a	0.74	17.2	14.1	67.9	30.6	8,013	0.80
IC-5a north dup	20050484a	0.58	16.6	11.4	71.4			
IC-5a north trip	20050484a	0.64	17.1	11.3	71.0			
IC-5b center	20050484b	1.52	22.0	16.9	59.6	37.3	9,795	0.98
IC-5c south	20050484c	0.78	23.3	17.6	58.3	35.1	10,104	1.01
IC-6a north	20050375a	0.00	22.9	27.1	50.0	41.4	13,149	1.31

Ecology and Environment ASI Job #25-063 Particle Size Distribution, % Moisture, and TOC Values - continued

Sample	ASI ID#	% Gravel	% Clay	% Silt	% Sand	% Moisture	TOC ppm	% TOC of
_								dry weight
IC-6b center	20050375b	0.00	25.8	28.1	46.1	45.0	12,574	1.26
IC-6c south	20050375c	0.00	30.2	32.3	37.5	46.4	13,699	1.37
IC-7a north	20050374a	0.00	40.2	43.1	16.7	57.5	19,281	1.93
IC-7b center	20050374b	0.00	38.5	42.0	19.5	53.6	17,005	1.70
IC-7c south	20050374c	0.00	29.1	30.9	40.0	55.0	16,862	1.69
IC-13a north	20050485a	1.12	12.0	9.36	77.5	26.4	7,077	0.71
IC-13b center	20050485b	4.05	12.4	8.18	75.3	26.1	6,904	0.69
IC-13c south	20050485c	0.88	12.8	11.9	74.4	28.2	7,400	0.74
IC-13c south dup	20050485c					28.3		
IC-13c south trip	20050485c					29.4		
IC-14a north	20050486a	0.00	33.1	32.5	34.4	45.3	12,726	1.27
IC-14b center	20050486b	0.00	31.6	32.9	35.5	46.4	14,520	1.45
IC-14c south	20050486c	0.00	30.4	29.7	39.9	43.6	12,238	1.22
MG-3a north	20050353a	17.5	3.91	1.31	77.2	22.1	2,853	0.29
MG-3b center	20050350	4.47	9.06	5.10	81.4	23.1	4,386	0.44
MG-3c south	20050353c	20.6	6.41	2.46	70.5	24.2	4,944	0.49
MG-4 center	20050351	9.01	9.38	4.05	77.6	22.9	6,763	0.68
MG-5a north	20050354a	5.71	7.65	3.27	83.4	23.0	4,577	0.46
MG-5b center	20050354b	5.22	8.66	6.71	79.4	26.7	4,682	0.47
MG-5c south	20050354c	6.20	9.81	9.07	74.9	26.3	6,704	0.67

APPENDIX G SEDIMENT DEPOSITION MODELING REPORT

G-1 PUBLIC



Sediment Deposition Resulting From Construction of a Natural Gas Pipeline Trench

Report Prepared For Ecology & Environment Inc. And Broadwater Energy

November 2005



One Blue Hill Plaza • Pearl River, New York 10965

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1.0 Introduction

Broadwater Energy has proposed to place a natural gas pipeline in a trench that will be plowed or dredged into the bottom sediment of Long Island Sound. HDR|LMS was requested to calculate the depth of sediment that will be deposited as a result of excavating the trench. This report details the methodology utilized to address the question and the results of the analysis.

This report can be read as an addendum to the report "Water Quality/Sedimentation Modeling Report for a Project to Construct and Operate a Liquefied Natural Gas receiving Terminal in Long Island Sound, New York", prepared by HDR|LMS and Ecology and Environment in October 2005. The work contained in this report utilizes the same three dimensional hydrodynamic and water quality model as described in the previous report, and builds on the results of that modeling effort.

2.0 Methodology

As before the MIKE3 model of New York Harbor and Long Island Sound, developed for the Corps of Engineers, was used in this study. The model had been previously modified to perform calculations related to the transport and dispersion of solids that could be resuspended during the trenching operation.

The parameters specified during the previous calculation included the volume of sediment resuspended, and the settling velocity of the resuspended solids. As the MIKE3 model considers solids as a group, as opposed to a collection of individually sized particles, the specification of settling velocity is of primary importance when calculating the deposition of the resuspended solids.

The subject of in-situ settling velocities in tidal and non-tidal systems has been studied extensively for over a century. The complexities in the process include particle flocculation, coagulation, turbulence effects, bed chemical and physical characteristics, shear effects on single and coagulated or flocculated particles, and biological influences. The range of calculated and measured settling rates is large and there is no correct value. Any value chosen can be argued to be both too small and too large. After extensive literature review (only some of which are cited in the references at the end of this report), a value of 1 mm/s was chosen for use in the model.

The model was run in exactly the same manner as the previous calculation, except that now the mass of sediment deposited to the bottom was tracked. At the end of the simulation the total mass deposited is output. This is spatially varying.

It is more intuitive to convert areal mass deposition into a depth. This is achieved by dividing the areal mass by the bulk density of the deposited sediment. This calculation is as follows:

```
A = Areal mass = kg/m^2
B = Bulk density = kg/m^3
Depth, D = A/B = m (* 1000 mm/m) = mm
```

The bulk density is the estimated density of the deposited solids. To be conservative the porosity of the deposited solids was assumed to be 90%, an extremely high value. The density of the solids was assumed to be 2600 kg/m³. The resulting bulk density is then:

```
Bulk density = porosity * density of water + (1-porosity)*density of solids

= 0.9 * 1000 \text{ kg/m}^3 + (1-0.9) * 2600 \text{ kg/m}^3

= 900 \text{ kg/m}^3 + 260 \text{ kg/m}^3

= 1160 \text{ kg/m}^3
```

3.0 Results

The results of the calculation are shown in Figures 1 through 5. These are the computed deposition depths at the completion of all trenching work. These do not include the two cable crossings or the tie in to the Iroquois Gas Transmission System.

The calculated maximum deposition depth anywhere along the route is just under 5 mm. The figures show that there are multiple points along the route where local maximums occur. These are most likely due to tidal effects and may coincide with slack water periods. In general it appears that depths greater than 1 mm only occur within 100m-200m from the route.

Given the limited spatial extent of deposition and the small resulting deposition depths it is unlikely that there would be any impact from the deposition of resuspended material from the trenching operation.

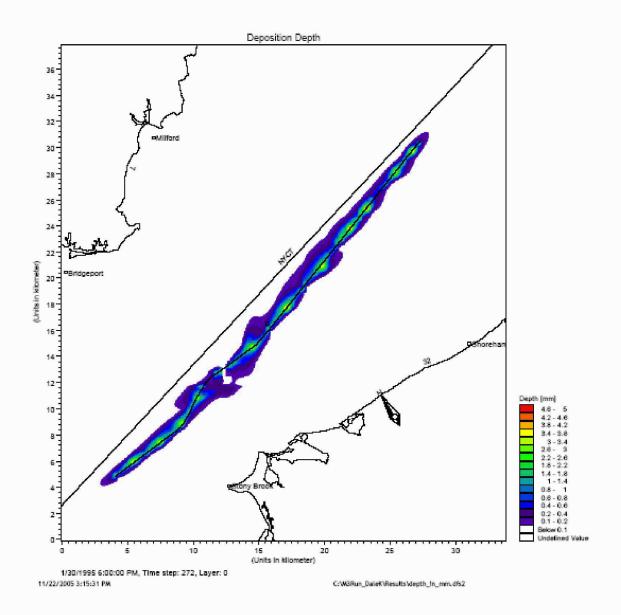


Figure 1. Deposition over entire route.

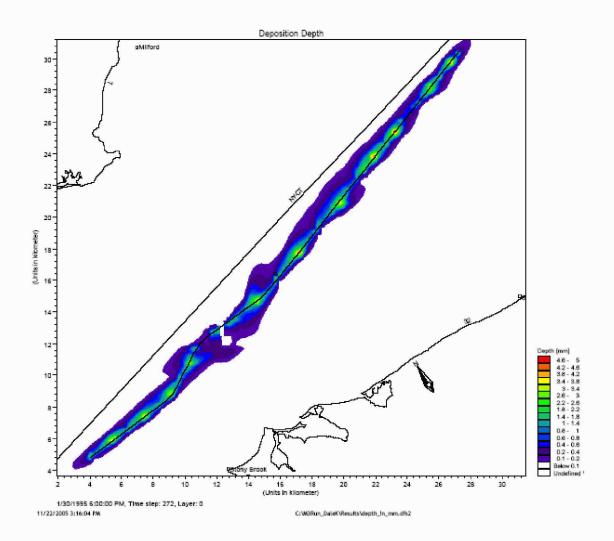


Figure 2. Closer view of deposition over entire route.

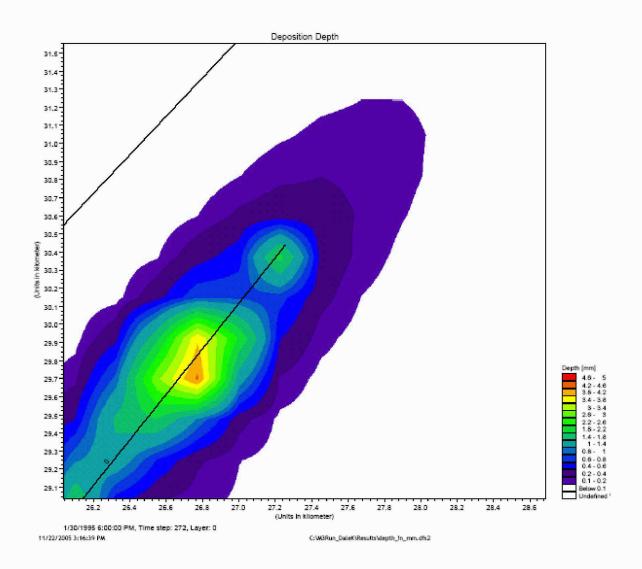


Figure 3. Deposition at start of route.

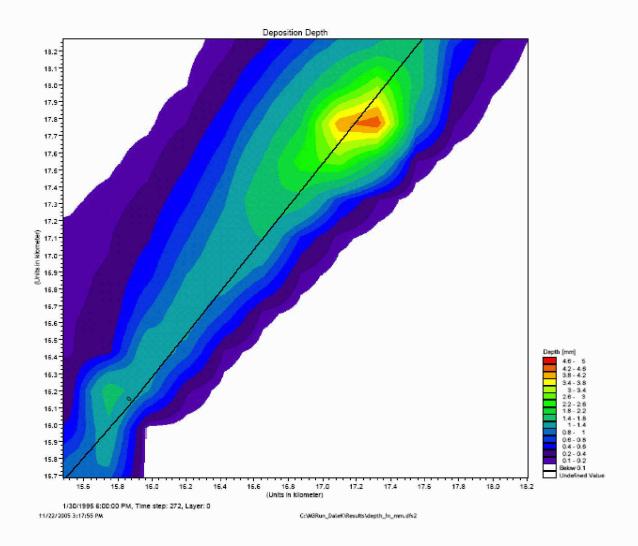


Figure 4. Deposition at middle of route.

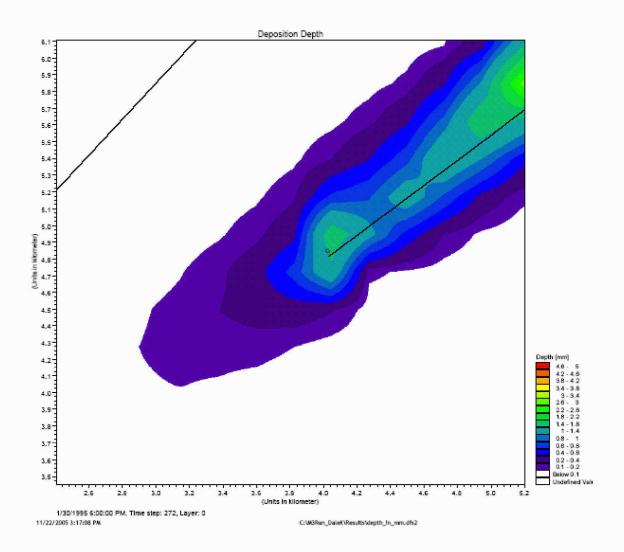


Figure 5. Deposition at end of route.

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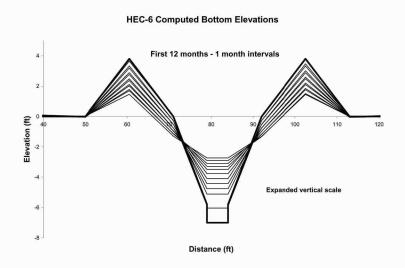
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APPENDIX H NATURAL BACKFILL MODELING REPORT

H-1 PUBLIC



Natural Backfilling of Natural Gas Pipeline Trench

Report Prepared For Ecology & Environment Inc. And Broadwater Energy

November 2005



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1.0 Introduction

Broadwater Energy has proposed to place a natural gas pipeline in a trench that will be plowed or dredged into the bottom sediment of Long Island Sound. HDR|LMS was requested to calculate how long it would take this trench to backfill by natural sedimentation and sediment transport processes. This report details the methodology utilized to address the question and the results of the analysis.

2.0 Methodology

A typical cross section of the trench is shown in Figure 1. This cross section is used as the basis of the model calculations.

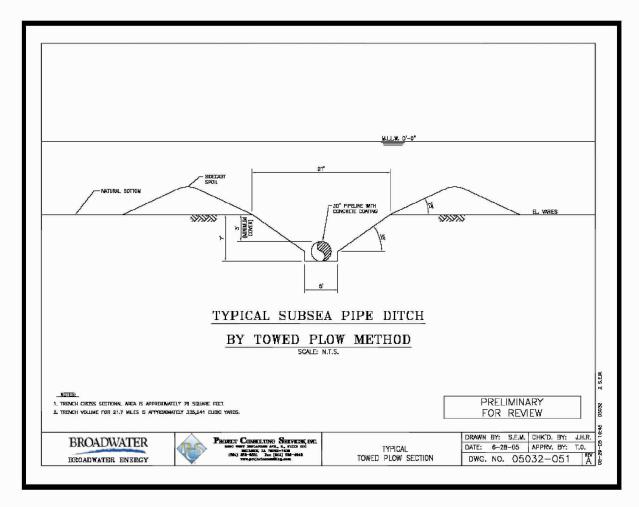


Figure 1. Typical trench cross section.

There are two processes that will act to fill the trench in:

- 1. Deposition from suspended solids in the water column
- 2. Transport of sediment adjacent to the trench into the trench

To enable the estimation of these processes, the Corps of Engineers HEC-6 model was chosen.

2.1 Corps of Engineers HEC-6 Model

The HEC-6 model contains all of the computational elements necessary to do sediment transport calculations but it is designed for use in rivers. There is no equivalent model available for estuarine situations, that is, a robust sediment transport that can be set up and run in a reasonable time frame. Therefore the HEC-6 model was set up and run in a manner that can be used to simulate the tidal conditions present in Long Island Sound. These set up and run details are described below.

HEC-6 is a one-dimensional movable boundary open channel flow numerical model designed to simulate and predict changes in river profiles resulting from scour and/or deposition over moderate time periods. A continuous flow record is partitioned into a series of steady flows of variable discharges and durations. For each flow a water surface profile is calculated thereby providing energy slope, velocity, depth, etc. at each cross section. Potential sediment transport rates are then computed at each section. These rates, combined with the duration of the flow, permit a volumetric accounting of sediment transport and bed sediment within each reach. The amount of scour or deposition at each section is then computed and the cross section adjusted accordingly. The computations then proceed to the next flow in the sequence and the cycle is repeated beginning with the updated geometry. The sediment calculations are performed by grain size fraction thereby allowing the simulation of hydraulic sorting and armoring.

2.2 Model Set Up

The model was set up to simulate a 500ft wide section of trench, as shown below in Figure 2. The flow is set perpendicular to the trench and the length of the section is 2000 ft. The length and width are arbitrary and were chosen to ensure that boundary effects are not an issue around the area of interest, i.e., the trench.

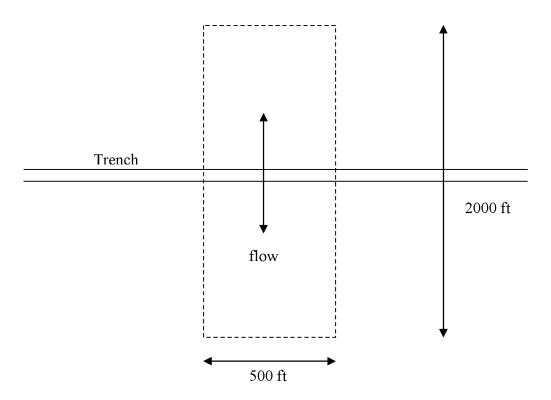


Figure 2. Schematic of HEC-6 model set up.

The trench profile is defined as shown in Figure 1 and includes both the excavated trench and the adjacent spoil piles.

The actual prevailing tidal direction crosses the trench at an angle that is less than the ninety degrees used in the model. The approximation to use a perpendicular flow significantly simplifies the modeling procedure and allows the geometry to be symmetrical when the flow direction is changed.

The model depth is based on the average depth at the locations of the three Acoustic Doppler Current Profiler (ADCP) units that were placed along the route. This depth is 72.9 feet. Over the course of the 22 mile long pipeline route, the depth varies from around 45ft at the Stratford Shoal to just over 100ft mid way along the route, with the average depth being close to that used in the model.

As the depths along the route are large compared to the details being modeled in the trench, (spoil piles only 3.8 ft high) any change in depth, from say 70 ft to 80ft, produces only a small change in model results.

The model water temperature is set to 50° F.

The model simulates the tidal motion by using time varying flow. The model uses a 1 hour time step. The ADCP data showed velocities varying from zero at slack water up to a maximum of around 2.5 ft/s. The velocities vary in the typical sinusoidal pattern associated with tidal systems. The model velocities were set to vary between zero and 1.5 ft/s. The upper value, 1.5 ft/s represents an average of the peak flood and peak ebb velocities during each tidal cycle measured by the three ADCP units.

Even though the prevailing currents are not at ninety degrees to the trench, as in the model set up, it is not appropriate to simply reduce the velocities geometrically (that is, consider only the component perpendicular to the trench). As the bottom sediments will be exposed to the full range of tidal velocities, these are used in the model. The approximation is that where particles scoured in the model will move perpendicular into the trench, or away from the trench, in reality they will move at an angle into, or away from, the trench. As such the net effect should be the same.

HEC-6, being designed for unidirectional river flows, can only simulate flow in one direction during any model run. In order to change the direction of flow, as occurs during a tidal cycle, each model run needs to stop at the end of every six hours, before the flow changes direction. The computed sediment profiles are then used as inputs for a new model run that has the flow coming from the opposite direction.

As the process of naturally backfilling the trench was expected to occur over a period of years, stopping and starting the model every six hours would be extremely time consuming. Some sensitivity tests were performed and the model was run for 30 days of temporally-varying flow in one direction and then the same magnitude of flow was reversed. During each run the flow continues to vary in a half-sinusoidal manner so the effect of varying velocity is still captured.

2.3 Model Sediment Input Data

2.3.1 Suspended Sediment

Based on typical data for Long Island Sound a suspended solids concentration of 25 mg/L was used. The particle size distribution of suspended solids in the Sound are not known, so the distribution was based on reported literature values for estuarine systems. These include works by Wolanski and Gibbs (1995), Hamblin (1989), Orton and Kineke(2001) and Gartner et al. (2001). HEC-6 has predefined sediment classes as shown in Table 1.

Table 1. HEC-6 Sediment Classes

HEC-6 Size Class	Material	Grain Diameter (mm)
Clay 1	Clay	0.002-0.004
Silt 1	Very Fine Silt	0.004-0.008
2	Fine Silt	0.008-0.016
3	Medium Silt	0.016-0.032
4	Coarse Silt	0.032-0.0625
Sand 1	Very Fine Sand	0.0625-0.125
2	Fine Sand	0.125-0.25
3	Medium Sand	0.25-0.30
4	Coarse Sand	0.5-1.0
5	Very Coarse Sand	1-2
6	Very Fine Gravel	2-4
7	Fine Gravel	4-8
8	Medium Gravel	8-16
9	Coarse Gravel	16-32
10	Very Coarse Gravel	32-64
11	Small Cobbles	64-128
12	Large Cobbles	128-256
13	Small Boulders	256-512
14	Medium Boulders	512-1024
15	Large Boulders	1024-2028

The distribution used in the model for the suspended solids was 25% clay (0.002- 0.004 mm diameter), 25% very fine silt (0.004 – 0.008 mm), 20% fine silt (0.008 – 0.016 mm), 10% medium silt (0.016 – 0.032 mm), 10% coarse silt (0.032 – 0.0625 mm) and 10% very fine sand (0.0625 – 0.125 mm).

The fall velocity of the suspended sediment is calculated in the model by using the Federal Interagency Sedimentation Project method (Williams 1980).

2.3.2 Bed Sediment

The particle size distribution of the solids in the bed sediment was based on data collected by Broadwater along the proposed pipeline route. The model bed sediment particle size distribution is shown below in Table 2.

Table 2. Model Bed sediment Particle Size Distribution

Mean Particle Diameter (mm)	Percent Less Than
8.0	100.0
4.0	99.0
2.0	97.0
1.0	96.0
0.5	95.1
0.25	79.7
0.125	63.0
0.062	48.0
0.031	33.0
0.016	18.0
0.008	0.0

The properties of the clay, silt and sand that comprise the suspended solids and bed sediment are detailed below:

2.3.2.1 Clay

The model calculates deposition of clay using the settling velocity but erosion of cohesive sediment is not allowed. The specific gravity of clay is set at 2.65. The shear threshold for clay deposition is set at 0.02 lb/ft². This number is obtained from Bureau of Reclamation (BOR) Tables as presented by Lowe (2003). The unit weight of compacted clay is assumed to be 78 lb/ft³, also given by the BOR. Uncompacted clay is set at 30 lb/ft³. The compaction coefficient is 16 lb/ft³ per year.

2.3.2.2 Silt

The model calculates the deposition and erosion of silt. The specific gravity of silt is set at 2.65. The shear threshold for clay deposition is set at 0.02 lb/ft². This number is obtained from Bureau of Reclamation (BOR) Tables as presented by Lowe (2005). The unit weight of compacted silt is assumed to be 82 lb/ft³, also given by the BOR. The unit weight of freshly deposited silt is set at 65 lb/ft³. The compaction coefficient is 5.7 lb/ft³ per year.

2.3.2.3 Sand

Sand transport is computed using Toffaleti's (1966) transport function. The specific gravity of sand is set to 2.65. The grain shape factor is set to 0.667. The exponent in the surface area exposed function calculation is 0.5. The Einstein bed load parameter is 30. The unit weight of settling sand is 93 lb/ft³.

3.0 Results

The results of the initial HEC-6 runs indicated that while the model was calculating erosion and deposition, the model was not allowing the material eroded from the spoil piles adjacent to the trench to actually deposit into the trench. Instead the material would be evenly deposited along the 1000 ft downstream portion of the segment. Some sensitivity tests showed that the large depth, nearly 73 ft, had effectively damped the geometry effect of the trench. Based on our extensive experience with dredged channels, we know that the highest sedimentation rates occur in the deepest areas and that much of the material deposited in the trench will remain there – hence the well documented problems that dredged channels experience with siltation.

In order to correct this issue an adjustment was made when the model was restarted at the end of each 30 day period. It was assumed that the material scoured from the upstream spoil pile would be deposited in the trench. Material scoured from the downstream spoil pile was assumed to have been moved away from the trench. The bottom elevation of the trench was then recomputed using the volume of the spoil piles that were scoured, and this elevation was used as input for the next run. The calculation includes an allowance for the fact that the trench geometry is not uniform with depth. For example at depths below 5.8 ft the trench is only 5 ft wide and tends to fill rapidly. As the depth decreases, the trench width increases, and hence the trench will fill at a slower rate. The volume of the trench that is occupied by the pipe itself is also considered when recomputing the new bottom elevations

When the trench is deep it can be assumed that all of the material that settles there is trapped. As the trench fills in the trapping efficiency will decrease. It was assumed that at depths greater than 4 ft below the bed, the trapping efficiency is 1.0, i.e. 100%. Between depths 3-4 ft, the trapping efficiency is reduced to 0.9. From 2 to 3 ft, the efficiency is 0.8; and at depths less than 2 ft, the efficiency is 0.7.

The model computed bottom elevations are shown in Figure 3. This figure shows the first 12 months of the simulation in 30 day (approximately 1 month) increments. Figure 4 shows the model computed bottom elevations for months 12 to 36 in 180 day (approximately 6 month) increments. By the end of 36 months the trench is essentially filled.

The pipe itself is covered by around day 200.

The model is also conservative in that no storm events that would cause increased bottom velocities, hence increased sediment transport, are considered. Storms were not considered because they are randomly occurring events, of varying magnitudes, directions and durations. There were also no data showing the effect of storms on bottom velocities in the vicinity of the trench. It is known however that storms are responsible for significant amounts of bed sediment movement and could deposit a large volume into the trench over a short period of time.

Over a three year period one would expect that Long Island Sound would experience several large storms that would contribute to filling the trench. Hence the model calculated time frame can be considered conservative.

HEC-6 Computed Bottom Elevations

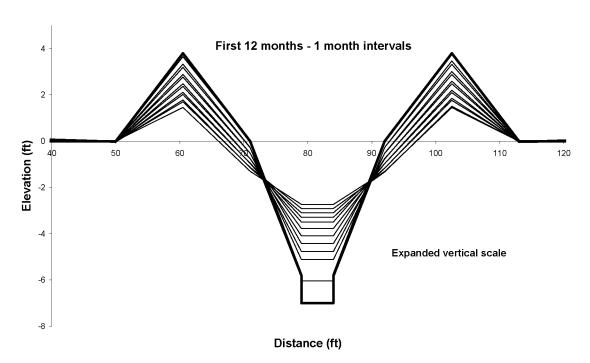


Figure 3. Computed bottom elevations for first 12 months.

HEC-6 Computed Bottom Elevations

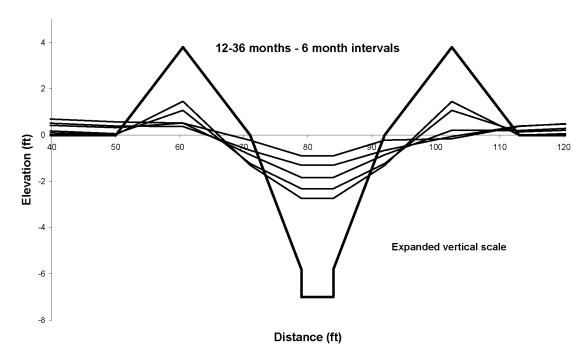


Figure 4. Computed bottom elevations for months 12 to 36.

3.1 Stratford Shoals

The model results described above can be considered indicative of what would occur along most of the route, where the sediment is a mixture of clay, silt and sand. In the area of the Stratford Shoals the sediment composition is primarily sand, or sand and gravel. No modeling was done specifically of the Stratford Shoals This section comprises approximately one mile of the 22 mile route.

Even though the ADCP located on the shoal showed maximum tidal velocities in the 2.5 ft/s range, these velocities are only likely to move small amounts of the heavy sand and gravel, that comprises the sediment of the shoals, into the trench. The shallow depth of the shoal (around 45 ft), and its prominent vertical relief indicate that high bottom velocities will occur during storm events. It is these storm-induced velocities that will be responsible for most of the sediment transport that will fill in the trench.

As mentioned previously, storms are random events in terms of occurrence, duration, strength and direction. For this reason no attempt is made to predict the timeframe over which the trench in the vicinity of the Stratford Shoals will be filled.

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APPENDIX I THERMAL MODELING REPORT

I-1 PUBLIC

COOK LEGACY COATING COMPANY

E&E Thermal Study Results Part One



BUILDING WATER SOLUTIONS
THROUGH INNOVATION

E&E Thermal Study Results

Part One



Broadwater LNG Project					
Document #:	R11290502				
Document Title:	Thermal Influence of the Natural Gas Sendout Pipe in the Long Island Sound Water Column				
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I. Introduction and Background

Ecology and Environment, Inc. (E & E) is currently working on the permitting of a new Liquid Natural Gas (LNG) terminal in Long Island Sound. A concern has arisen over the thermal impact of the natural gas transmission pipeline. To address this concern E & E has approached Cook Legacy Coating Company (Cook Legacy) to develop a thermal model that will identify and quantify the thermal zone of influence caused by the flow of 120 degree Fahrenheit natural gas through an exposed pipe in water that varies seasonally from approximately 35 degrees to 70 degrees Fahrenheit. As the subcontractor to Cook Legacy, Northwest Hydraulic Consultants (nhc) is responsible for the model development and CFD simulations.

II. Project Goals

The general goal of this project is to quantify and assess the thermal zone of influence of the pipe. The goal of Phase One is to generally characterize the thermal zone of influence of the transmission pipeline. This analysis will identify the potential problem and characterize the thermal zone of influence around the pipe.

III. Model Set Up

Physical Layout

The transmission pipe is anchored to the mooring tower leg, as shown in Figure 1.



Figure 1: Physical Model Layout

30" Pipeline Anchored to mooring tower.

4.5" Separation distance b/w pipeline and jacket

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The Part One study modeled a ten foot section of pipeline near the water surface. The modeled physical structure was the mooring tower leg and the pipe. The modeled flow was 0.8 f/s parallel to the physical structure. The model layout is shown in Figure 2.

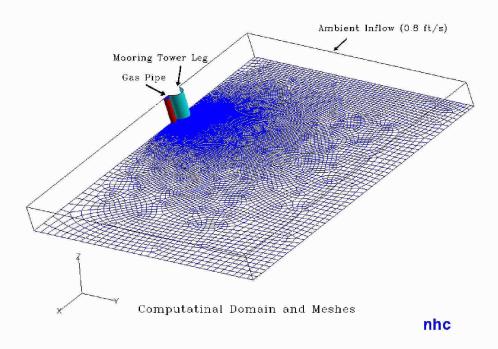


Figure 2: Model Set-Up

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Seawater Characteristics

DIMENSION	VALUE	SOURCE	NOTES
Density	1016.6 kg/m^3	Derived from formula for seawater density at temp. pressure, and salinity.	T=25 deg C, S=26ppt Near surface.
Viscosity	.9488 centipoise	Derived from formula for seawater viscosity at temperature, pressure, and salinity.	Same inputs as above
Salinity	25.7ppt	Environmental Sampling Report	24.7 ppt min, 25.7 ppt mean 26.6 ppt max
Temperature	77 deg F And 38 deg F	Environmental Sampling Report	Max and min.
Current	.8 ft/s	Environmental Sampling Report	Gas pipe directly behind the wake of tower leg

Figure 3: Seawater Quality Inputs

Natural Gas Characteristics

DIMENSION	VALUE	SOURCE	NOTES
Capacity	1440 mmcfd	Input from E&E	
Pressure	1220 psig	Input from E&E	
Temperature	120 deg F	Input from E&E	This is a worst case scenario.

Figure 4: Natural Gas Characteristics

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Pipeline Characteristics

DIMENSION	VALUE	SOURCE	NOTES
Diameter	30"	Input from E&E	
Wall Thickness	.617"	Input from E&E	This is the minimum wall thickness, it is used as a worst case thickness
Grade	API 5L Gr. 70	Input from E&E	This is a worst case scenario.
Thermal Conductivity	50 W/m- K	Input from E&E	
Length	120°	Defined area to be modeled	

Figure 5: Pipeline Characteristics

Modeled Outputs and Iterations

The FSRU transmission line could interact with the surrounding water environment in two separate ways. First, the transmission line could impact overall water quality by changing water temperatures due to heat transfer from the hot gas, through the pipeline and into the surrounding water. This concern was addressed by modeling the area around the pipe to assess the size of the impacted area and the degree of impact within that area. Second, the increased heat on the pipe itself could impact the habitat or behavior of benthic life. In order to approximate the temperature along the pipe surface, a plot of surface temperatures was rendered.

The above iterations were run at low temperature and high temperature conditions.

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IV. Results

Results for Maximum Ambient Water Temperature

Figure 6 shows the flow characteristics around the mooring tower and the transmission pipe. Note the area of low flow within the wake zone of the mooring tower leg.

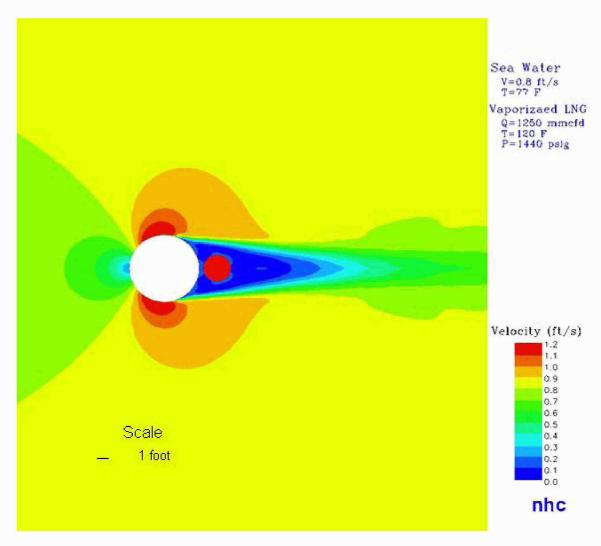


Figure 6: Flow Characteristics of the Mooring Tower Leg and Transmission Pipe

Figure 7 shows the thermal contours around the pipe and the mooring tower. The greatest thermal impact occurs within the low flow area between the mooring tower and the transmission pipe. The dark blue color indicates ambient temperature. Note that even

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in this worst case scenario, the area of water around the transmission line changed by the transmission line temperature is less than the pipe diameter.

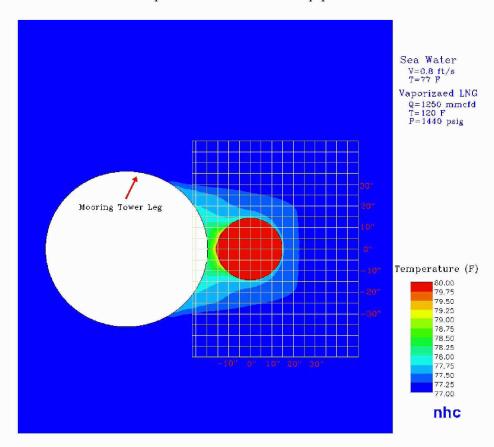


Figure 7: Thermal Contours in Maximum Temperature Condition
Figure 8 plots temperature as a function of distance from the mooring tower leg. Note the rapid return to ambient moving away from the transmission pipe.

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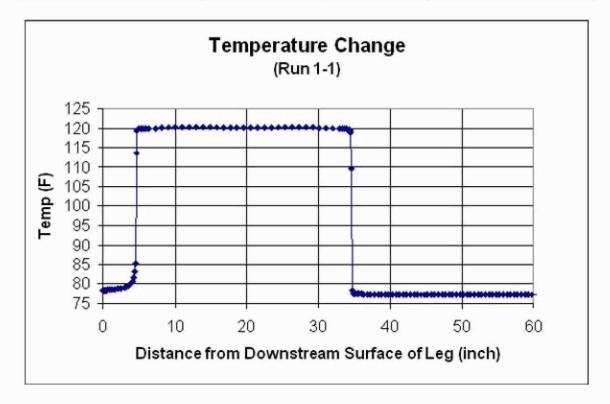


Figure 8: Temperatures in Water Local to the Transmission Pipe in Maximum Temperature Condition

Because the increased surface temperature may have an impact on aquatic life, a plot of surface temperatures was rendered.

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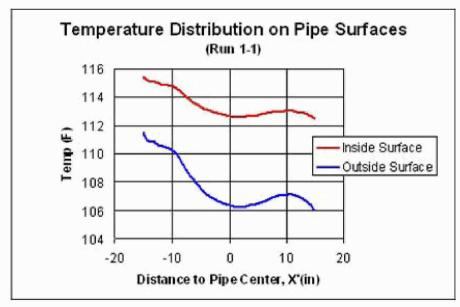


Figure 9: Temperatures on Inside and Outside of Pipe Surface in Max Temperature Condition Results for Minimum Ambient Water Temperature

Figure 10 shows the thermal contours at minimum temperature condition. The size of the thermal zone of influence and the degree of change are greater than in the maximum flow condition, but still very small. This reflects the greater overall difference between the temperature within the transmission line and the ambient water.

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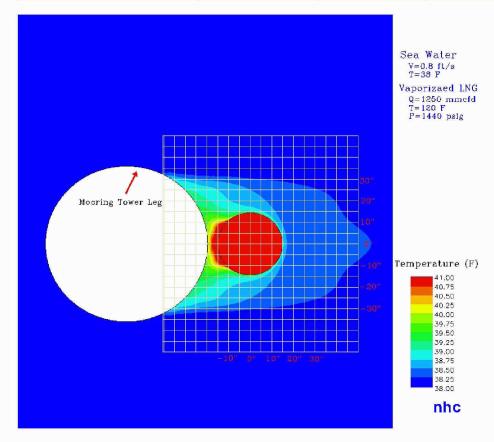


Figure 10: Thermal Contours in Minimum Temperature Condition

Figure 11 plots temperature as a function of distance from the mooring tower leg within the minimum temperature condition. There is a noticeable increase in temperature within inches of the transmission pipe on the mooring tower side. Figure 12 shows the surface temperatures on the inside and outside surface of the pipeline. Notice that there is a boundary effect causing cooler temperatures on the interior surface of the pipe.

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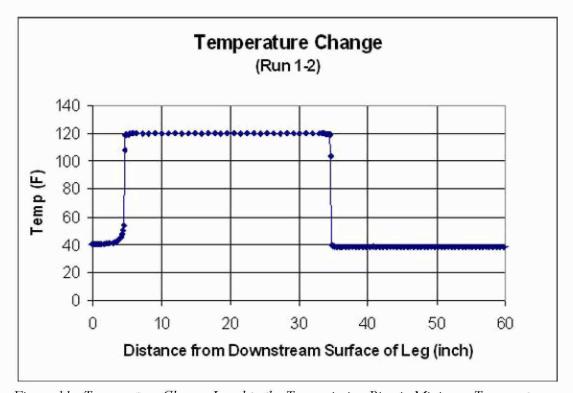


Figure 11: Temperature Change Local to the Transmission Pipe in Minimum Temperature Condition

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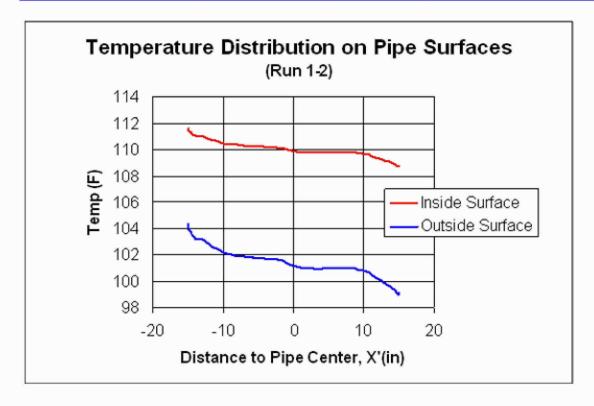


Figure 12" Temperature on Inside and Outside Pipe Surface in Minimum Temperature Condition

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Conclusions

The CFD Analysis suggests that even in the worst case scenario, the thermal influence of the pipeline is small. The greatest impact occurs between the pipeline and the mooring tower leg. The outside surface of the pipe is warmed, which may have a minimal impact on aquatic life within a very small area.

COOK LEGACY COATING COMPANY

E&E Thermal Study Results Part Two

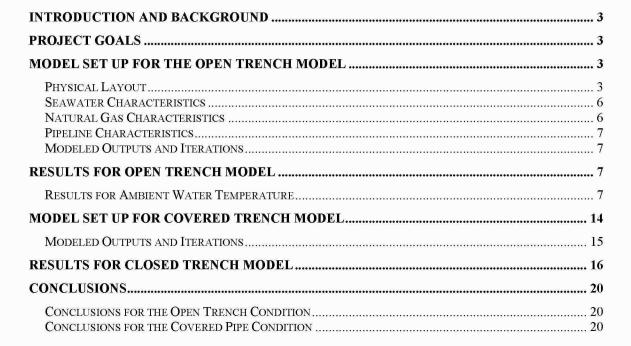


BUILDING WATER SOLUTIONS
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E&E Thermal Study Results

Part Two

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	Broadwater LNG Project		
COATING COMPANY	Document #:	R11290502	
	Document Title:	Thermal Influence of the Natural Gas Sendout Pipe in the Long Island Sound Water Column—Horizontal Pipe in Trench Model	
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Introduction and Background

Ecology and Environment, Inc. (E & E) is currently working on the permitting of a new Liquid Natural Gas (LNG) terminal in Long Island Sound. A concern has arisen over the thermal impact of the natural gas transmission pipeline. To address this concern E & E has approached Cook Legacy Coating Company (Cook Legacy) to develop a thermal model that will identify and quantify the thermal zone of influence caused by the flow of 120 degree Fahrenheit natural gas through a pipeline in water that varies seasonally from approximately 35 degrees to 70 degrees Fahrenheit. As the subcontractor to Cook Legacy, Northwest Hydraulic Consultants (nhc) is responsible for the CFD simulations. **Project Goals**

The general goal of this project is to quantify and assess the thermal zone of influence of the pipe. The goal of Phase Three is to assess the thermal zone of influence of the horizontal pipe in the trench. This will be modeled at the ambient temperature in two conditions—an open trench model with flow parallel to the pipeline, and a closed trench model with three feet of sediment cover over the existing trench. These analyses will identify potential problems and characterize the thermal zone of influence around the pipe line and within the trench.

Model Set Up for the Open Trench Model

Physical Layout

The transmission pipe is anchored to the mooring tower leg, as shown in Figure 1.



Figure 1: LNG Terminal and Transmission Pipeline

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The Part Two study modeled a 100 foot pipeline in the trench. The modeled physical structure is the trench, the sea floor, soil below the sea floor and the water near the bottom of the sea floor. The modeled flow was 0.8 f/s parallel to the pipeline. The 0.8 ft/sec. magnitude is the mean current velocity. The parallel direction was defined by the worst case intersection between the pipeline and prevailing east to west direction of flow. The plan for the subsea trench is shown in Figure 2.

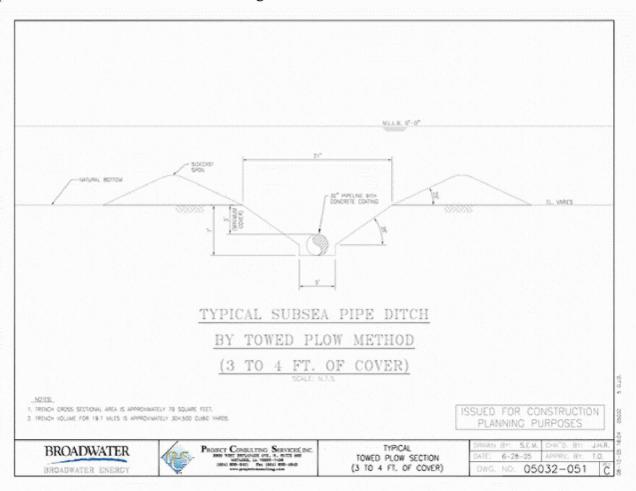
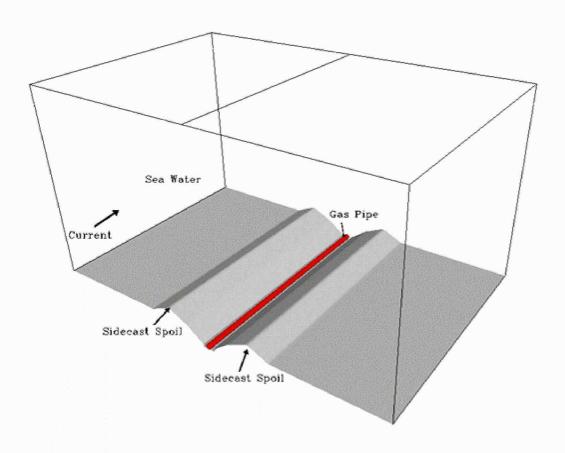


Figure 2: Plan for Subsea Pipe Trench

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The computational domain for the analysis was based upon the pipe location and orientation within the subsea ditch. Within the computational domain the pipe is shown settled 1" into the bottom settlement. This will reflect reality and will improve the modeled interface between the pipe and the soil. Figure 3 defines the computational domain of the open trench scenario.



CFD Simulation Domain for Bare Pipe in Trench

nhc

Figure 3: Computational Domain for Open Trench Condition

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The attributes of the pipeline, natural gas, and water are shown within the following tables. The model assumed no heat transfer into the deep soil. This assumption also supported our goal of a worst case scenario.

Seawater Characteristics

DIMENSION	VALUE	SOURCE	NOTES
Density	1020.545k g/m^3	Derived from formula for seawater density at temp. pressure, and salinity.	T=44.3 F, S=26ppt 90' Depth
Viscosity	0.0015197 kg/m-s	Derived from formula for seawater viscosity at temperature, pressure, and salinity.	Same inputs as above
Salinity	25.7ppt	E&E Environmental Sampling Report	24.7 ppt min, 25.7 ppt mean 26.6 ppt max
Temperature	44.3 deg F	E&E Environmental Sampling Report	Cp=4035.4 J/Kg-K Thermal Conductivity: 0.573421 W/m-K
Current	.8 ft/s	E&E Environmental Sampling Report	Flow approximately parallel.

Figure 4: Seawater Characteristics

Natural Gas Characteristics

DIMENSION	VALUE	SOURCE	NOTES
Capacity	1440 mmcfd	Input from E&E	
Pressure	1220 psig	Input from E&E	
Temperature at Inlet	120 deg F	Input from E&E	This is a worst case scenario.

Figure 5: Natural Gas Characteristics

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Pipeline Characteristics

DIMENSION	VALUE	SOURCE	NOTES
Diameter	30"	Input from E&E	
Wall Thickness	.617"	Input from E&E	This is the minimum wall thickness, it is used as a worst case thickness
Grade	API 5L Gr. 70	Input from E&E	This is a worst case scenario.
Thermal Conductivity	50 W/m- K	Input from E&E	
Length	120"	Defined area to be modeled	

Figure 6: Pipeline Characteristics

Modeled Outputs and Iterations

Because flow is modeled parallel to the trench line and the heat transfer interaction will change along the 100' modeled length. Temperature contours were taken at several cross sections. The local temperature on the pipe surface, the mean temperature within the pipe, and the mean temperature within the 75" diameter region were also assessed.

Results for Open Trench Model

Results for Ambient Water Temperature

Figure 7 shows the thermal contour cross sections at 25', 50', 75' and 100'. Note the increase in the physical size of the thermal zone of influence and the increase in local water temperatures between the 25' cross section and the 100' cross section. Note that the red area indicates any temperature above the max temperature scale.

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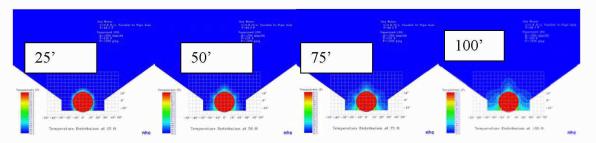


Figure 7: Change in Thermal Zone of Influence at Increasing Distance from the Inlet: Scale 44 Degrees F to 120 Degrees F

Figure 8 shows the 25' cross section. The thermal zone of influence is small and confined to the area around the pipe. Other than the small area below the pipe that is greater than 64 degrees F the max temperature within the area of water impacted by the pipe is 49 degrees F.

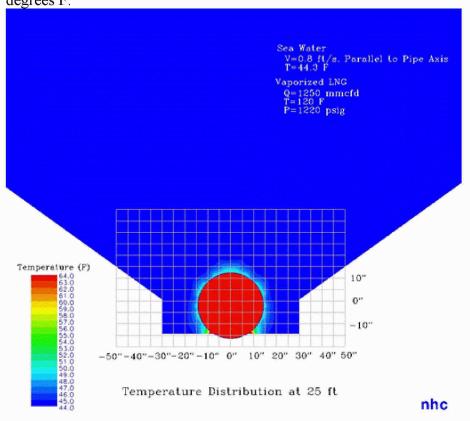


Figure 8: Thermal Contours at 25' from the Inlet Scale 44 Degrees F to 64 Degrees F

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Figure 9 shows thermal contours at 100'. Note that the thermal zone of influence has increased, both in terms of the physical size of the impacted area, and the maximum temperatures.

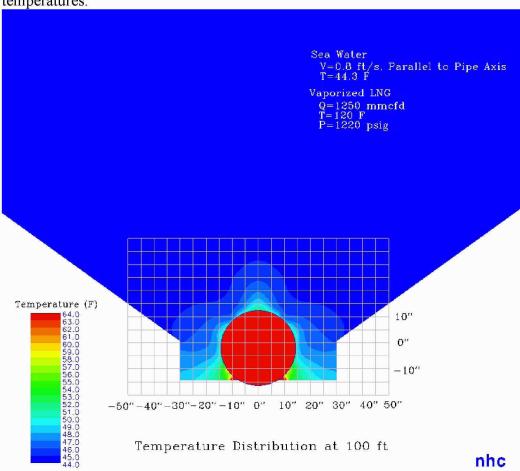


Figure 9: Thermal Contours at 100' from the Inlet Scale 44 Degrees F to 64 Degrees F

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Figure 10 shows average temperature in gas as a function of distance along the pipe. The overall change is approximately 1.8 degrees over the 100' pipe run. This reflects heat being transferred through the pipe to the water. The rate of heat transfer will decrease along the length of the pipe as the temperature distribution between the pipeline and the ambient water environment approach equilibrium.

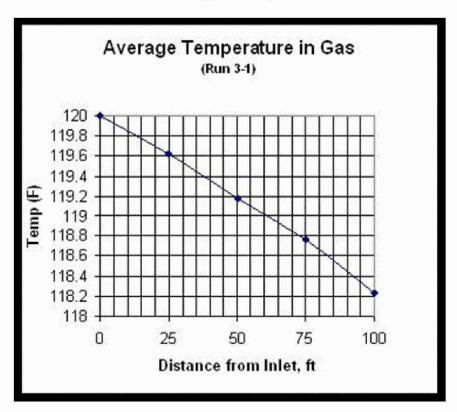


Figure 10: Delta T within the Pipeline

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Although the temperature contours illustrate the change in water temperature at various points along the pipe line, they do not provide data on the mean temperature within the pipe vicinity. The mean delta T assesses the overall impact of the transmission pipeline. Figure 11 identifies the area in which there was an appreciable thermal impact.

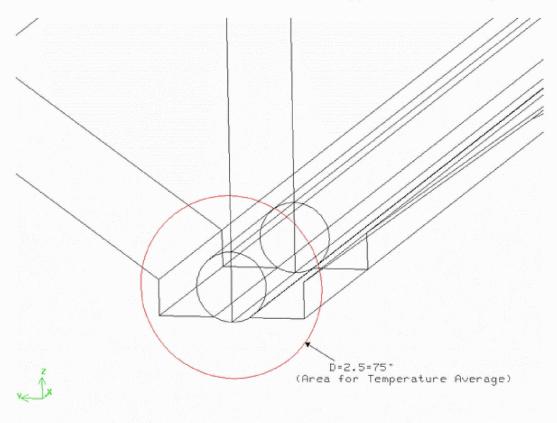


Figure 11: Domain for Assessing Mean Temperature

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Figure 12 shows the average temperature within the 75" diameter area as a function of distance from the inlet. The overall change in average temperature is approximately 1.45 degrees over the 100' pipe run.

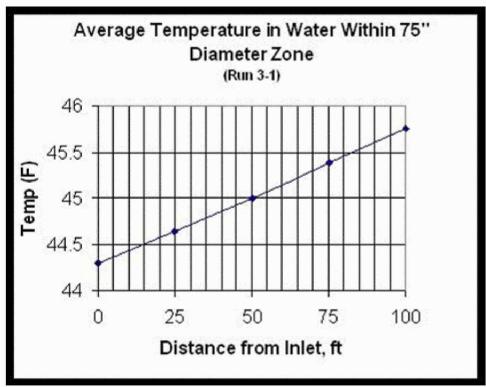


Figure 12: Change in Water Temperature

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The final item of concern for the open trench model was the temperature along the surface of the pipe. The maximum, minimum, and mean temperatures are shown as figure 13.

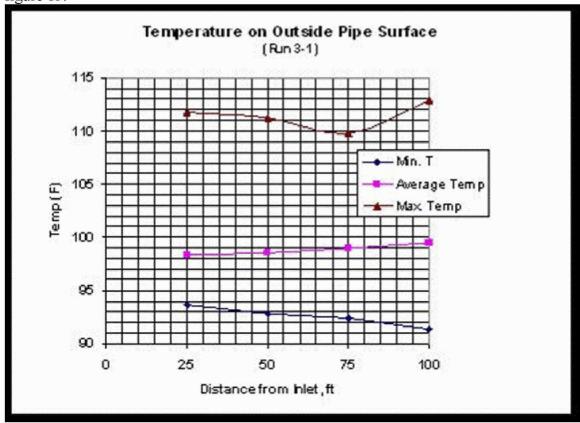


Figure 13: Pipe Surface Temperatures

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Model Set Up for Covered Trench Model

The general model set up for the covered trench condition was similar to the open trench condition. The pipe qualities, sea water qualities, and general physical layout were the same. There were two major differences between the open trench and covered pipe models. The first and most obvious difference was that the covered pipe model included soil above the pipe. The soil depth was established as 3' as this was the minimum soil depth per the trench plan. The second difference was also related to the soil—in the open trench case we assumed no heat transfer to the deep soil. In this case heat transfer properties were applied to the soil. Figure 14 shows the computational domain including the soil.

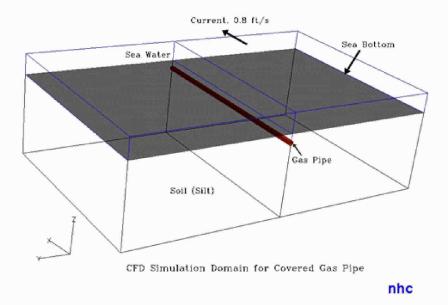


Figure 14: Computational Domain for the Covered Pipe Condition

The physical and heat transfer properties of the soil were important for the covered trench model. Figure 15 summarized the soil attributes used in this model and where applicable the derivation of these attributes.

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DIMENSION	VALUE	SOURCE	NOTES
Soil Type	Silt	Input from E & E based upon sampling and expected material for backfill.	
Conductivity	3.6 VV/m- K	Max conductivity from the range provided by Virginia Geotechnical	Range was 1.7- 3.6 watts/meter-k
Heat Capacity	2500 j /kg-K	Min heat capacity per range provided by Virginia Geotechnical	Range was 2500- 4000 j kg-1 k-1
Temperature	44.3 deg F	Ambient soil temperature modeled the same as seawater	
Density	90 pcf	Input from E & E	1441.67 kg/m^3
Cover	3 feet	Minimum backfill coverage	Per trench drawing

Figure 15: Soil Characteristics

Modeled Outputs and Iterations

The goal of the model was to assess the thermal impact of the pipe in general, and specifically the maximum temperature change within the upper 6" of sediment. As such the model outputs were temperature contours of the pipeline illustrating the thermal change, temperature contours focusing on the area above the pipeline, and plots of local temperatures as a function of distance from the pipe.

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Results for Closed Trench Model

Figure 16 shows the temperature contour around a cross section of the pipeline. The scale includes the maximum and minimum temperature. This model illustrates the small thermal influence along the sea floor.

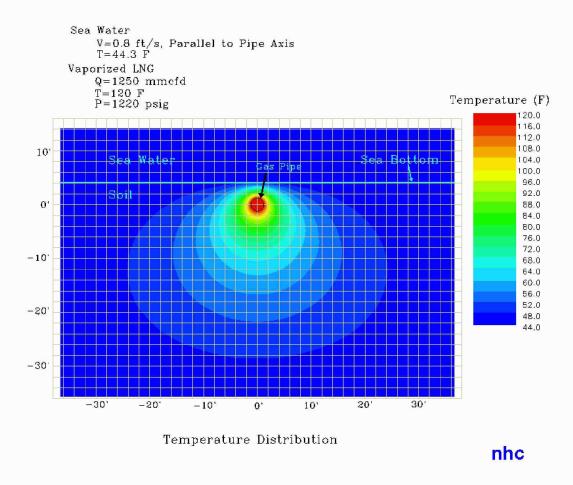


Figure 16: Thermal Contours Around Covered Pipe: Scale 44 Degrees F to 120 Degrees F

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In order to assess the change in temperature around the pipe, Figure 16 was reploted with a scale between the ambient 44 degrees F and the ambient + 20, or 64 degrees F. This is shown in Figure 17. It shall be noted that temperature above 64 degrees F is all shown in red. With this representation it is clear that although the overall magnitude of warming is small, there is noticeable warming between the pipe and the sea floor.

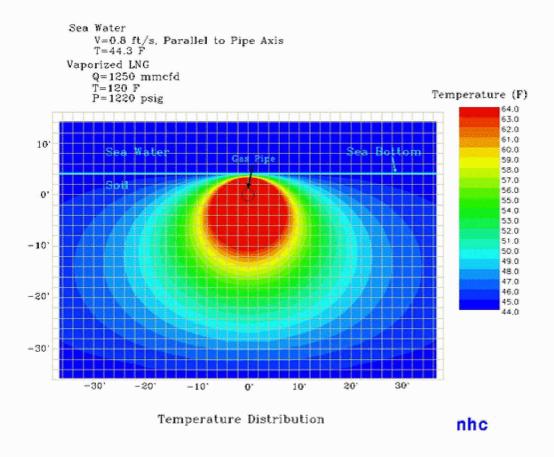


Figure 17: Thermal Contours Around Covered Pipe: Scale 44 Degrees F to 64 Degrees F

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Based upon research on benthic life, E&E was concerned with a temperature increase greater than 10.8 degrees F within the top 6" of sediment. To assess the delta T within this region we zoomed in on the area above the pipe. This is shown in Figure 18. In general, in the upper 6 inches of sediment, the delta T is less than 10.8 degrees F, or temperature is <55.1 degrees F. Directly above the pipeline, there is a small area in which the delta T is greater than 10.8 degrees F or > 55.1 degrees F.

Temperature Distribution

```
Sea Water
V=0.8 ft/s, Parallel to Pipe Axis
T=44.3 F
Vaporized LNG
Q=1250 mmcfd
T=120 F
P=1220 psig
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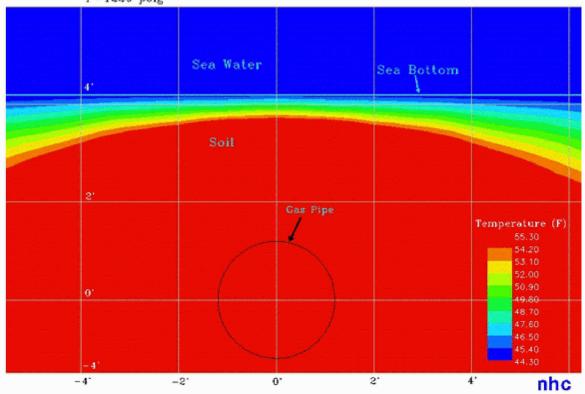


Figure 18: Thermal Contours Above the Pipe Scale 44.3 Degrees F to 55.3 Degrees F

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Figure 19, "Temperature on Sea Bottom," provides the temperature as a function of distance from the pipe centerline. In other words point 0 is on the ocean floor 3' above the pipe center. The peak magnitude of warming above ambient temperature is minimal.

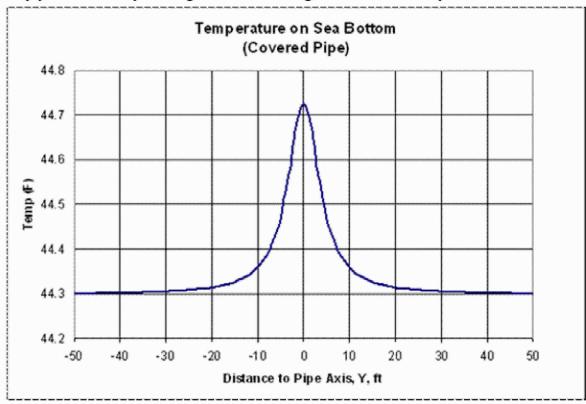


Figure 19: Temperature on Sea Bottom

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Conclusions

Conclusions for the Open Trench Condition

- •• With the parallel current condition the thermal zone of influence is significantly larger at the end of the 100' section than at the beginning.
- •• This reflects the cumulative warming of the water traveling along the canal.
- •• In this scenario the overall change in temperature was approximately 1.45 degrees F over 100' of pipe or .0145 degrees F per foot.
- •• The warming impact will continue to grow as water travels along the pipeline in the parallel direction.
- •• The mean temperature along the pipe surface is between 97 and 100 degrees. The maximum temperature varied between 112 and 115 degrees. However, the maximum temperature occurs in a small area near the corners of the pipe bottom.
- •• This reflects the cumulative warming of the water traveling along the open trench. However, this assumes the worst-case impact scenario of parallel flow, when in fact normal flow conditions are generally perpendicular to the trench. Under normal flow conditions, the cumulative affect of the warm water traveling and expanding in the open trench is not likely to occur. It is expected that any warm water in the open trench will mix and assimilate with the surrounding water outside of the trench, which will return it to ambient temperature conditions.

Conclusions for the Covered Pipe Condition

- •• The maximum delta T on the surface occurs directly above the pipe. The overall change is approximately 0.45 degrees F.
- •• The largest thermal impact occurs in the area immediately adjacent to the pipe and declines quickly within a few feet. Within this area the temperature ranges from approximately 115 degrees on the pipe surface to approximately 100 degrees one foot away.
- •• The delta T within the upper 6" of sediment is less than 10.8 degrees within most of the space. There may be a small contour directly above the pipe in which delta T is 10.8 degrees.